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AN INTRODUCTION TO ARTIFICIAL INTELLIGENCE AND MARINE SYSTEMS APPLICATIONS

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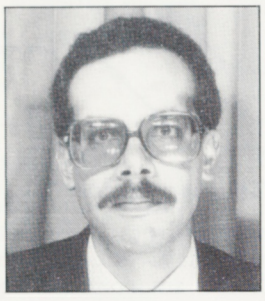
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AN INTRODUCTION TO ARTIFICIAL INTELLIGENCE AND MARINE SYSTEMS APPLICATIONS

by

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TABLE OF CONTENTS

1. INTRODUCTION
2. ARTIFICIAL INTELLIGENCE
   - 2.1 Definitions
   - 2.2 Historical background
   - 2.3 Search and reasoning
   - 2.4 Current difficulties in AI
3. EXPERT SYSTEMS
   - 3.1 General description
   - 3.2 Basic expert system components
   - 3.3 Knowledge base
   - 3.4 Inference mechanism
   - 3.5 Types of expert systems
   - 3.6 Features of viable expert system applications
   - 3.7 Assessment of expert systems
   - 3.8 Knowledge acquisition
   - 3.9 Rule Induction from examples
   - 3.10 Basic notation
4. KNOWLEDGE REPRESENTATION AND AI SOFTWARE
   - 4.1 Declarative system
   - 4.2 Procedural representation
   - 4.3 Forward Production Systems
   - 4.4 Backward Chaining Systems
   - 4.5 Frame Systems
   - 4.6 AI languages and their environments
   - 4.7 Object oriented programming
5. BUILDING EXPERT SYSTEMS
   - 5.1 Review of fundamental principles
   - 5.2 Construction framework for expert systems at LR
     - 5.2.1 An overview of the approach
     - 5.2.2 Information Analysis Expert System: IAES
     - 5.2.3 IAES hierarchical network model
   - 5.3 Rule Induction. EXTRAN.
   - 5.4 AI development environment MUSE
   - 5.5 Setting up an application in MUSE
6. MARINE APPLICATIONS
   - 6.1 A general marine technology expert system
   - 6.2 Specific marine technology expert systems
     - 6.2.1 Expert voyage planning
     - 6.2.2 A marine fuel oil characterisation expert system
     - 6.2.3 Diesel engine fault diagnostic expert system
     - 6.2.4 Maintenance expert system
     - 6.2.5 Integrated ship control
     - 6.2.6 Dynamic positioning expert system
     - 6.2.7 Offshore platform design
7. CONCLUSIONS
8. ACKNOWLEDGEMENTS
9. REFERENCES

APPENDICES

SUMMARY

For many years it has been promised that computer based systems which have elements of "intelligence" will have a major impact on the work of engineers. Recent developments have brought these promises near to reality. The impact of artificial intelligence on the work of the Society and its surveyors will, at some time in the future, be very significant. The concepts should be affecting the development of future policies to ensure that these are compatible.

The subject matter inevitably involves many ideas and methods which are complex and can be daunting to the uninitiated reader. Many unfamiliar terms are used. This paper aims to provide, in a concise form, an introduction to the basic concepts and principles before describing in detail some of the projects which are being undertaken under the Society's Research and Development programme. It is an area of work which could have a profound effect on Surveyors and their work, perhaps even threatening their livelihood. As such the Author hopes that readers will bear with the terminology where this appears difficult to comprehend, concentrating on the conceptual ideas. Coming to terms with the jargon is an essential part of gaining familiarity with the expert system.

1. INTRODUCTION

The past decade has seen a steadily increasing number of studies about the application of artificial intelligence (AI) in every branch of science and engineering. This has been stimulated by the successful development of expert systems since the mid-1960s. Collaborative efforts by experts and artificial intelligence specialists have produced systems which diagnose disease, evaluate military threats and even prospect for minerals, at a level of performance equal to or surpassing human expertise. The potential power of systems, which not only replicate expensive or rare human knowledge, but which are capable of producing cumulative versions of it has

stimulated worldwide efforts to develop and apply this technology. In time, expert systems will influence all areas of human activity where knowledge provides the means for solving problems.

During the same period of intense activity in artificial intelligence research, fundamental changes have taken place in the world shipping industry. These led to a serious decline of shipbuilding activity and profitable ship operation. Because there have been few advances in new technology applications, marine transport continues to be a low technology industry compared with the electronic, computer, communications and even air and road transport industries. This possibly provides one of the reasons for the "vicious circle" type of recession which has afflicted the industry for the past decade, (Fig. 1).

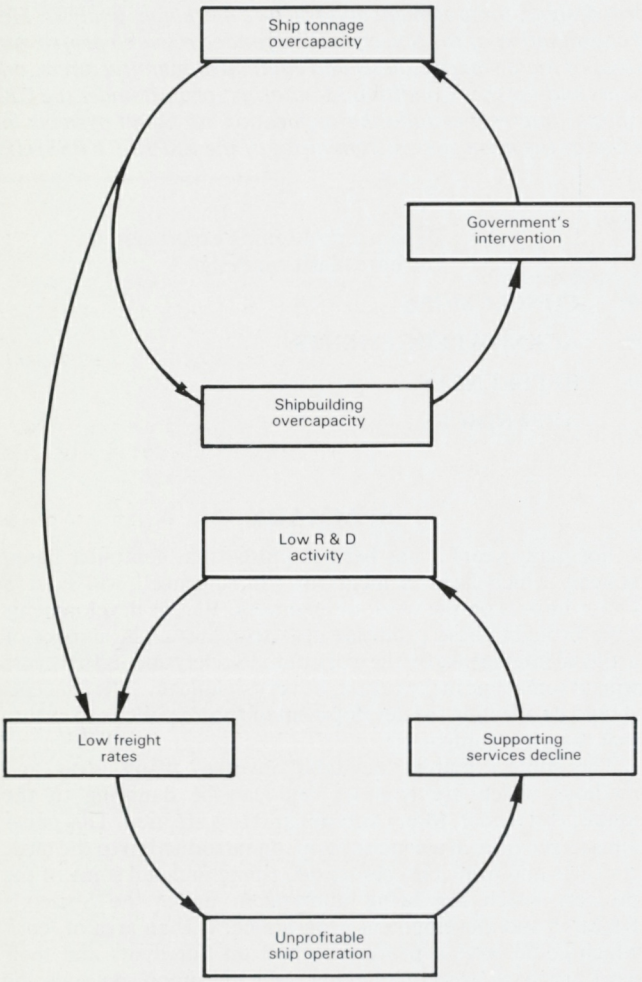


Fig. 1 An overview of the marine transport industry

However, it is inevitable that general progress in technology will lead to the application of high technology in shipping. Many projects, the "efficient ship" schemes, currently in progress have this objective firmly in mind.

Marine transport encompasses shipbuilding and operating which, as in many other industries, continue to exist as completely separate functions. Both shipbuilding and ship operation are highly competitive international businesses. Today countries with high labour costs are seeking to improve their efficiency by developing and exploiting computer-based technologies, (Fig. 2). The flexibility offered by automation in manufacturing makes robotic systems particularly suited to shipbuilding. The industrial robot can be used in a variety of complex manufacturing tasks and is highly developed for welding and plate-cutting operations.

To meet the present shipbuilding economic demands, the new generation of shipbuilding robots need to comply with two

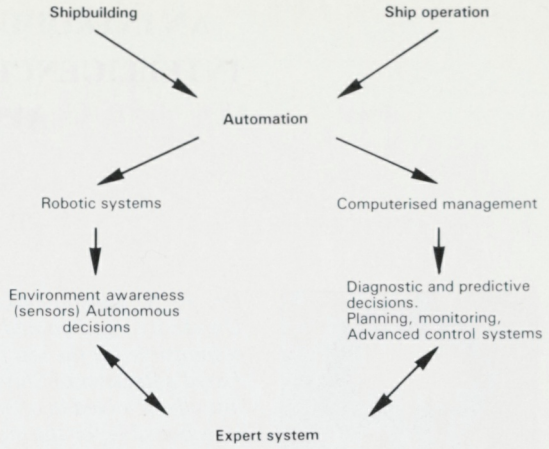


Fig. 2 Future Sea Transport Features

requirements. The first is enhanced awareness of the environment, for which new sensory systems are needed. The second is improved in-built intelligence for autonomous decision making. This means that future systems will have to replicate and apply autonomously what amounts to human expertise. The process adjustments can then be made as required without intervention. To further this aim "knowledge engineering" can provide the technology for converting human knowledge into industrial power.

In the ship operation sector the technical objectives are remarkably similar. Moves towards enhanced operational flexibility and computerised ship management will require the application of the technologies of advanced electronics, computers, instrumentation and communications. Knowledge based systems would provide a means of extending automation by making systems independently capable of diagnostic and predictive decisions. The expert system will be asked to produce a coherent picture of the ship environment based on uncertain and changing conditions, such as wind and sea states, economic factors and ship performance data.

Historically, industrial automation has been a visible and clearly identifiable main product of the high technology era. An extension and acceleration of this trend is the inevitable route to the future. Although artificial intelligence can be seen to have a direct influence and part to play in this process, a second important aspect of AI within the changing technological environment is the transfer of knowledge to expert systems.

Knowledge in any subject is usually of two kinds, public and private. Public knowledge includes the facts and theories which appear in text books and references. Private knowledge consists largely of rules of thumb and generalisations that have come to be called "heuristics". Heuristics enable the human expert to make educated guesses—especially where information is incomplete, or an unusual combination of conditions are involved. The ability to recognise and select promising approaches to problems with uncertain or incomplete data, and to check quickly whether results from complex analytical computational methods are realistic, is a very important part of human decision making in engineering. However, this expertise is slowly becoming eroded by the increasing use of computers to solve problems in a manner which is not fully understood by the decision maker. This means that transferring currently available knowledge into expert systems, so that it can be used efficiently by present and future users, is becoming an important issue.

In summary, expert systems will be a key factor in manufacturing and operational developments. These developments could eliminate certain of the traditional engineering skills which must be replaced by storing actively existing knowledge. If saving knowledge and then employing it to enhance industrial effectiveness proceed in unison, then the full benefits of this new technology will be obtained. The place of AI

in ship transport and classification in the future is summarised in Fig. 3. However, many sophisticated items of hardware and software are frequently accompanied by impressive claims. A great deal of effort is required both in resolving important difficulties in AI technology and adapting it for practical use in the marine field.

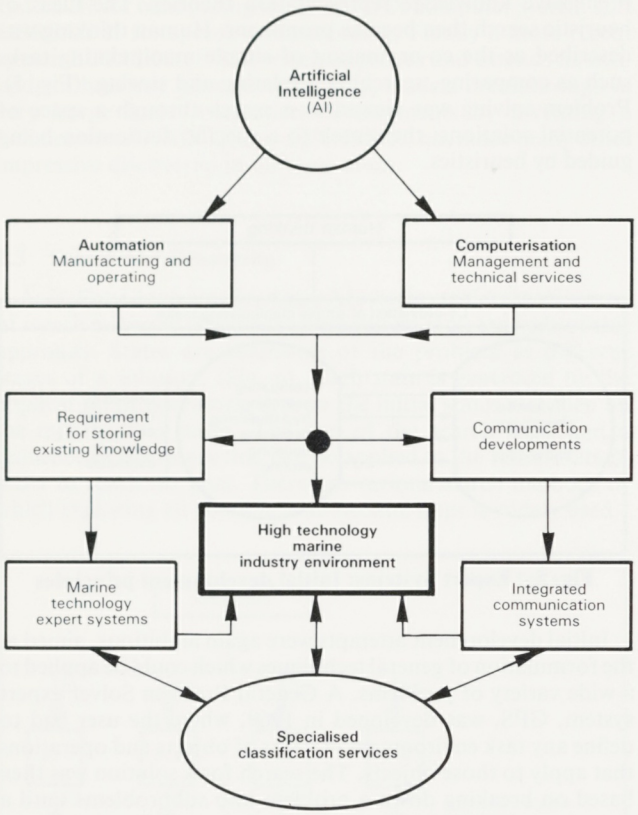


Fig. 3 Future AI impact in the Marine industry

Within the Society experience has been gained by investigating artificial intelligence applications in various marine technology aspects. In the engineering research programme two AI prototypes have been developed: fuel oil characterisation and engine fault diagnosis. More recently the Society joined the Danish-led ESPRIT Project "Shipboard installation of knowledge based systems". (ESPRIT is the European Strategic Programme of Research in Information Technology funded by the EEC). This is aimed at the development of an integrated expert system the role of which is to support the master and officers in optimising the safe and economic operation of merchant vessels. Overall, the Society's research programme in this area coincides with the framework of a number of information technology and national "ship of the future" programmes. As such the Society will be able both to draw on the experience gained and contribute in turn to the upgrading of marine technology. The experience and knowledge which is being accumulated can also be used for evaluating the advantages and limitations of the new technology. More important, its impact on safety and integrity can be independently assessed for future applications in automation and real time control.

There are thus four areas where AI and LR activities meet:

The assessment of practical AI applications particularly in automation and real time control.

The storing of current technical expertise for the training of and utilisation by the Society's surveyors.

The integration of AI based classification services within an upgraded ship technology environment.

The integration of technology management and corporate strategy.

In the following text, the main AI principles and the tools for building expert systems within the Society are described. A review of marine applications is presented with emphasis on the prototype systems currently under development in the Society's R & D programme.

2. ARTIFICIAL INTELLIGENCE

2.1 Definitions

Most people today have some idea about what artificial intelligence means since the range of well-published applications in medicine, science and engineering is constantly increasing. In this Information Technology era, books, articles and references about AI have reached even the most isolated technical or scientific communities. The interest in this field is certainly understandable. AI researchers are trying to create computer programs that "think" in a way that only man has thought until very recently. The very idea that machines can think is intriguing. It creates sceptisism as to how far we can go, it raises questions about many practical issues and generates concern about the consequence of having intelligent machines.

As it is difficult to answer precisely what AI is, a picture of this discipline can be produced through the following well known definitions.

> "Artificial intelligence is the science of making computers do the things which, if performed by humans, would be termed intelligent."
>
> "Artificial intelligence is the study of how to make computers do things which, at the moment, people do better."
>
> "AI is the study of computer techniques for solving problems by exploiting efficiently knowledge about a problem domain."

The first definition makes the essential point that AI is concerned with making "smart computers" by engaging in human-like cognitive processes such as learning. The next definition is a bit more interesting as it says something about the goals. AI is, at least in part, directed at the development of a better understanding of the human thought process. A new field of study called cognitive science has emerged to investigate this area. As "knowledge engineering" catalyses a global effort to collect, codify, and utilise applicable knowledge forms, clarification and expansion of the human knowledge process itself can be achieved.

The last definition brings things nearer to an engineering reality by referencing an implementation approach. It highlights the fact that the key to intelligent problem solving lies in reducing the random search for a solution by making use of knowledge. Most problems can be cast in the same form as the search for a path from some initial state to a desired final state which is regarded as the goal. The network of possible routes leading from the initial conditions to the goal is viewed as a search space. Both the definition of the search space and the guiding of the search process requires the application of specialized knowledge. The central role of knowledge in intelligence explains why the most successful AI programs so far have been expert or knowledge based systems which operate in specific subjects. In short, expert performance depends critically on expert knowledge and the effective handling of that knowledge (comprehension and recall).

To move from the general to the specific, there are three principal divisions of artificial intelligence: fundamental research, applied research and cognitive science, (Fig. 4). The first

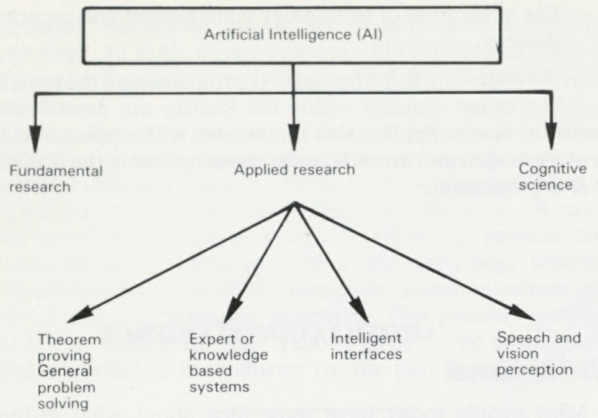


Fig. 4 Principal AI divisions

is directed at the development of techniques for progressing towards the artificial intelligence goals mentioned previously. For example much work is currently devoted to developing systems for presenting knowledge in a computer usable form which will remove some of the limitations of the previous systems. The second type of AI activity is directed at the development of programs that have some specific applied purpose, usually in industrial, scientific and administration sectors. One of the main divisions of this activity is the expert or knowledge-based system which "knows" about some particular subject and can "reason" about that subject at an expert level. The third type of AI activity is directed towards understanding the way that the human beings use knowledge. The AI aspect with the most direct engineering interest is the expert system which will be dealt with in some detail in the following sections.

2.2 Historical Background

Some forty years ago a British mathematician who had spent the war years developing code-breaking techniques turned his attention to a concept which had fascinated men for ages. Science fiction writers had penned stories of machines which could act in a humanoid manner, and which could demonstrate a high level of intelligence. Having been actively involved in the development of early electronic computers Alan Turing began to consider if it was possible for machines to behave intelligently and how this could be established or refuted. At that stage computers were in their infancy. To think of an intelligent machine represented a very major advance. However, Turing demonstrated that a certain very primitive computing machine could compute anything that was computable. All the people in science at the time, as well as the philosophers began wondering whether the brain is a Turing machine. From these beginnings the formal initial AI objective, to provide a means of programming intelligence into machines was set. In the following years researchers tried to build intelligent computers by imitating models of the brain as neuron networks. What was conveniently overlooked was the fact that the human brain contains 10 billion neurons each one being a very advanced form of an analogue device. More important, the proposed structuring of the neuron networks was shown to be an inadequate model of the brain.

The first period of AI research was dominated by a naive belief that reasoning models coupled with powerful computers would produce expert or superhuman performance. The severely limited power of general purpose problem solving strategies was soon realised and was well accepted in the late 1960s. In reaction to the limitations in the initial AI goals which expected that intelligent computers would be able to learn natural languages, write poetry, write music and so on, many researchers concentrated on application problems. What has happened since the early days, by and large, is a general reduction of the AI expectations. Artificial intelligence these days is commonly projected as being solely concerned with expert systems.

By the mid-1970s several expert systems had began to emerge. A few investigators who recognised the central role of knowledge in these systems initiated efforts to develop comprehensive knowledge representation theories. The ideas of heuristic search then became prominent. Human thinking was described as the co-ordination of simple manipulating tasks such as comparing, searching, updating and storing, (Fig. 5). Problem solving was viewed as a search through a space of potential solutions; the search to a specific destination being guided by heuristics.

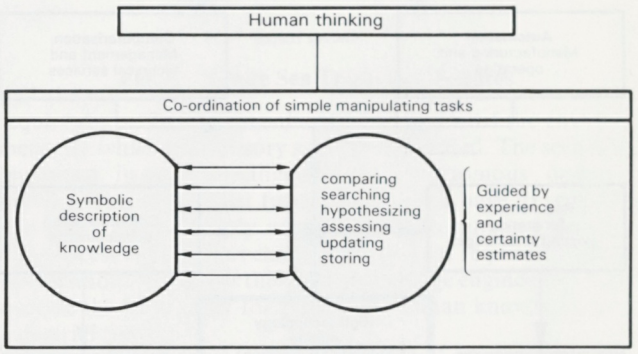


Fig. 5 Expert Systems: Initial development principles

Initial development attempts were again ambitious, aimed at the formulation of general techniques which could be applied to a wide variety of problems. A General Problem Solver expert system, GPS, was developed in 1969, where the user had to define any task environment in terms of objects and operations that apply to those objects. The search for a solution was then based on breaking down a problem into subproblems until a point is reached where each unit problem is small enough to be solved directly. The success of this general purpose expert system was limited. Other investigations aimed at producing powerful or general knowledge representations were also proved unsuccessful. A lesson learned was that expert knowledge is the key to expert performance; the knowledge representation and inference schemes merely provide mechanisms for its use.

The first successful expert system was the mass-spectrogram interpreter DENDRAL[1], which recently entered its sixteenth year. DENDRAL analyses chemical experimental data to infer the possible structures within a known compound. It employs an efficient variant of generate-and-test in its problem solving method. Its generator can enumerate every possible organic structure that satisfies the input data constraints. Partial molecular structures are first generated consistent with the data and then elaborated in all possible ways. By systematically generating all plausible structures DENDRAL finds even those less obvious candidates that human experts occasionally overlook.

The second best known expert system is MYCIN [2, 3] (1976) which has been even more influential. MYCIN addresses the problem of diagnosing and treating bacterial infections of the blood. Several new features were introduced which have become the hallmarks of the expert system. Its knowledge comprises approximately 400 rules relating possible blood conditions to associated interpretations. The rules are probabilistic. A scheme was devised based on "certainty factors" to allow the system to reach plausible conclusions from uncertain evidence. Probabilities, "fuzzy logic" and certainty factors are today used in the majority of expert systems to derive an estimate of the truth when the system works with fragmentary and inaccurate information. Finally, MYCIN can explain its

own reasoning processes. The user can interrogate it in various ways by enquiring why it asked a particular question or how it reached an intermediate conclusion.

There are many other well known expert systems which were produced successfully in the late 1970s. They include the PROSPECTOR in geology which found a previously unknown deposit of the valuable mineral molybdenum. The expert system RI for configuring the DEC VAX computer system and HERSAY II for speech-understanding. Finally a more recent system EURISKO (1982), which improves and extends its own body of heuristic rules automatically, made a breakthrough in very Large Scale Integration developments by inventing a 3-dimensional AND/OR gate. EURISKO has made many other impressive discoveries in different areas.

2.3 Search and Reasoning

As indicated previously, many AI systems make extensive use of search methods. The state-space system is an example of this approach. States are snapshots of the problem at different stages of a solution, (Fig. 6). Each state is generated by the application of operators, first on the initial states and then on the intermediate states. The aim of the search is to find a sequence of operators that can be applied to the initial state in order to reach the goal. There are various search methods of which exploring all possible intermediate steps is widely used.

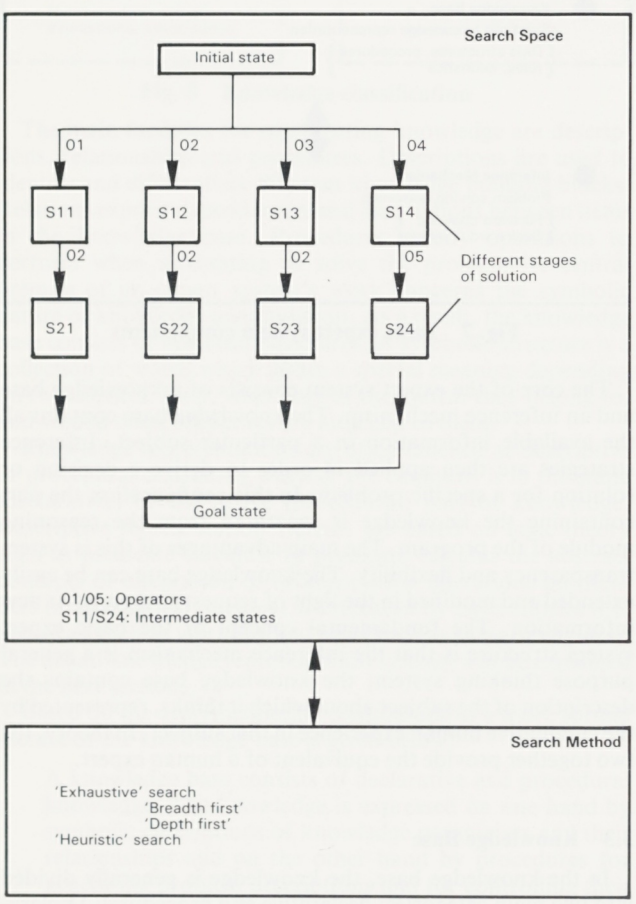


Fig. 6 "State-space" search

The underlying search space of AI problems with practical significance prohibits a systematic consideration of all the alternatives. For example, if the initial state of a problem was that a ship's speed is reduced, and the goal was to identify the cause, the possible number of combinations of engine, propeller and hull faults would be enormous. This is even more pronounced if we consider the possible movements of the blackpieces in response to all possible movements of white pieces in a chess game. The efficiency of the search process is hence particularly important in AI applications. A number of techniques are available to give high search efficiency in specific problem categories.

Search is sometimes formulated as a "generate and test" process in which possible solutions are generated and then immediately eliminated if they fail to meet some constraint. Another way of creating a search space is the "progressive charting refinement" of a subject which allows search to be carried out in a number of stages. In the first stage a global subject "map" provides overall directions. The details can then be established in a "local" map.

For many applications it is possible to apply specialised information to guide the search process. Such information can be a mixture of mathematical theory and heuristics. Heuristics can be expressed numerically or by rules. Numerical heuristics are functions estimating the closeness of a search path to a goal. To be useful, evaluation functions must characterise the solution space adequately which requires a substantial amount of knowledge. Arithmetic functions with weighted coefiicients can only partly represent such knowledge. Heuristic rules in symbolic computing are necessary in many cases.

Reasoning is often based on creating assumptions or hypotheses and revising the consequent system's beliefs in the light of the new knowledge received or derived. The revision process can be facilitated if the dependencies amongst the current set of hypotheses are known. For example if a hypothesis is made that both a fuel pump and the turbocharger of an engine are faulty, it will be useful to know whether these two faults interact weakly or strongly on another parameter such as the fuel consumption which can be measured. Dependencies can be analysed before an assumption is confirmed or retracted. Some hypothesis revision systems keep track of assumptions and inferences by recording justifications for them in a dependency network. Dependency directed reasoning can be extended to the problem solving process itself by introducing justifications about goals and constraints. Alternatively the solution process can be guided by fixed searching methods or heuristics.

2.4 Current Difficulties in AI

Despite the significant achievements of the past decade, AI technology is still at a research phase. It is not a finished engineering science. Some AI programs can be regarded as experiments which will be partly disregarded as soon as they have been developed and tested. The successful principles they embody provide the basis for further experimentation.

Key issues which have been established during the relatively short AI history are search and knowledge representation. Given a particular language for expressing knowledge the task of the solution method is to explore the resulting representation space. Many powerful knowledge representation systems, reasoning techniques, search mechanisms and supporting software have been established.

The main difficulties in AI relate to fundamental principles which normally provide a solid framework in any established engineering or scientific subject. Such principles include the definition and classification of the application, the theoretical foundations, and the assessment procedures for a solution.

AI can be applied in almost every subject. As a result, the definition and classification of the AI application area is not clear. For example, in medicine, human illness is classified in terms of pathology, osteopathy, neurology and so on. Such a classification scheme for expert systems has not been established. A challenge to AI is to specify which knowledge representation schemes are suitable for different categories of problems. Then, to demonstrate which solution methods perform well on each of the representations.

The only theoretical basis of AI is logic. However, heuristics rather than theory are often the corner stones of expert systems. The nature of the subject is such that many AI researchers believe that the use of any theoretical constraint is undesirable. Yet, this view is not supported by the majority. When fundamental principles for each class of application are established, certain methodology advantages will emerge.

In many practical cases it is important to be able to predict the main characteristics of a solution, having adopted certain techniques to produce it. Such performance prediction in AI investigations is not possible at present. For example, it is not possible to estimate which knowledge representation and inference mechanism will give the fastest execution time in a specific application. Also validation of expert system presents difficulties as traditional methods cannot be used.

The problems for which expert systems are being developed do not have a clear specification. Consequently, there is not standard or reference against which the performance can be judged.

As mentioned previously, an important application of AI is in storing knowledge. However, this process refers to empirical and specific knowledge rather than "pure" knowledge. It is possible for example to store knowledge in an expert system which will offer advice on underwater corrosion. Unfortunately the same knowledge cannot be re-used in an expert system for engine corrosion aspects. This is because machine learning is at a very early stage of development. Also it is not possible to reproduce "dynamic knowledge" (i.e. knowledge acquired by practice such as in learning to drive).

3. EXPERT SYSTEMS

3.1 General Description

Traditionally, an expert system is a computer program designed to simulate the use of expert human knowledge in a specific area. The knowledge is organised in such a form (typically symbolic representation of information and reasoning rules) that the program can offer intelligent advice or make an intelligent decision from given information.

There are several distinguishing features in expert systems. They include symbolic knowledge representation, symbolic inference and heuristic search facilities. Self-knowledge is employed to reason and rationalise the system's behaviour, and to provide explanations or justifications for conclusions reached. Advanced expert systems will be able to expand and refine their own range of capabilities[4].

In terms of applications, expert systems can be applied to many of the problems which are characterised by complexity, uncertainty and the absence of formalised solution (e.g. legal reasoning or medical diagnosis). Mathematical analysis does not provide a means for describing problems with many possible answers or different levels of abstration, or where only tentative conclusions can be made from incomplete and diverse sources of information. Solution in these cases depends primarily on the capacity to manipulate problem descriptions and to apply relevant pieces of knowledge selectively. Expert systems are ideally suited for these problems, although may not always provide a satisfactory solution.

A central notion of intelligent problem solving is that the system must construct its solutions selectively from a set of alternatives. This can be achieved in expert systems by using specialised knowledge to suggest promising solution routes and to identify useful data early. As in the case of human experts, high system performance depends on the ability to use knowledge effectively.

3.2 Basic Expert System Components

Fig. 7 shows the basic representation of an expert system. The first component is an input/output module. Its main function is to provide a language interpreter for communications between the user and the expert system. In the input mode, problem descriptions are supplied by the user. In the output mode, explanations of decisions reached by the expert system are provided. Furthermore, the system can provide evidence for and against alternative decisions which may be suggested by the user. For expert systems operating in real time the input/output interface provides a filtering device for information received from sensors or other information sources. The output in the form of advice or warning is either sent to computer screens or can be linked to alarm or control systems.

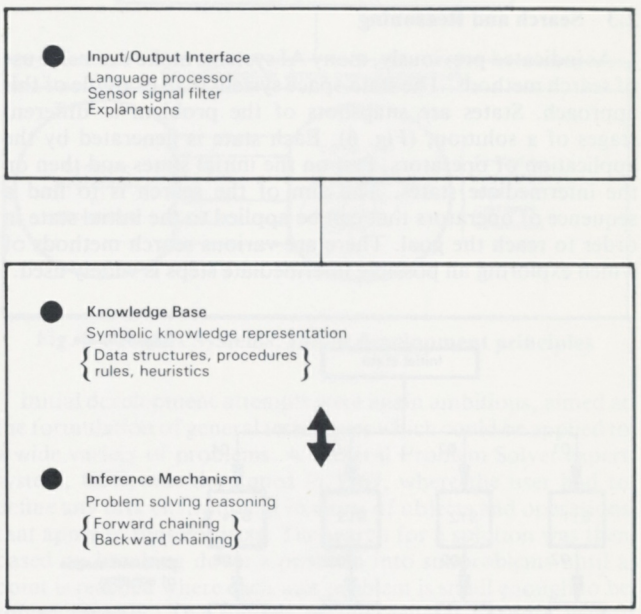


Fig. 7 Basic expert system components

The core of the expert system consists of a knowledge base and an inference mechanism. The knowledge base contains all the available information in a particular subject. Inference strategies are then applied in order to derive a decision or solution for a specific problem. In this configuration the part containing the knowledge is separated from the reasoning module of the program. The main advantages of this is system transparency and flexibility. The knowledge base can be easily extended and modified in the light of requested changes or new information. The fundamental concept of the basic expert system structure is that the inference mechanism is a general purpose thinking system; the knowledge base contains the description of the subject about which it thinks, represented by the cumulative human experience in that subject. In theory, the two together provide the equivalent of a human expert.

3.3 Knowledge Base

In the knowledge base, the knowledge is generally divided into two main categories: declarative and procedural. Declarative knowledge is the data or facts describing a subject. The procedural active part of knowledge provides a means for using the declarative knowledge efficiently. When an expert system is running (operational mode), procedures generate new facts or new hypotheses in a working memory space, describing the current state of the problem. The activation and scheduling of operations and the initiation of alternative solution routes can be co-ordinated by control knowledge. An assessment module can provide the tests required by the control functions.

Assessment knowledge provides the means to evaluate expressions, relations or procedures on the basis of pattern matching criteria or certainty factors. The described knowledge classification scheme is illustrated in Fig. 8.

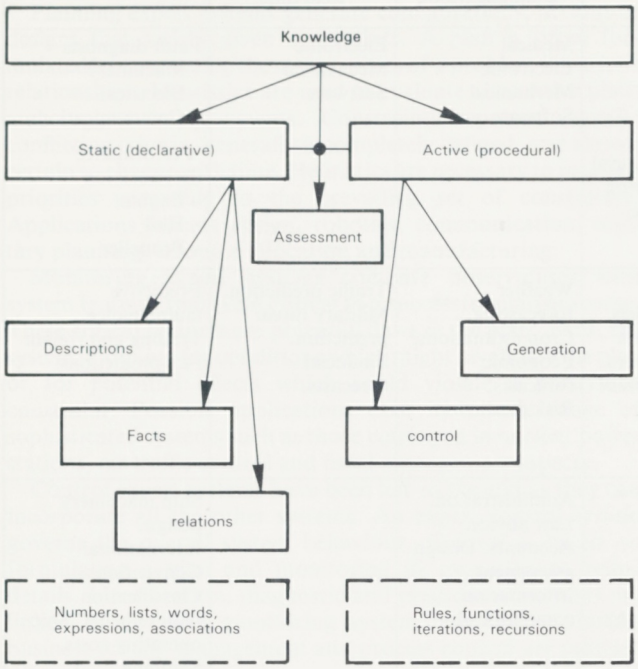


Fig. 8 Knowledge classification

The main facilities for representing knowledge are descriptions, relationships and procedures. Descriptions are used to identify and differentiate different knowledge building blocks. Relations express dependencies and associations between items in the knowledge base. Procedures specify operations to perform when attempting to solve the problem. A central premise of an expert system's work concerns the symbolic nature of knowledge manipulation. As a result, the knowledge base consists of symbolic structures. A symbolic structure is a collection of words which attain a special meaning depending on two aspects. First, what part of the system they belong to, and second what properties are attached to them.

Knowledge representations are often labelled as descriptive or procedural depending whether the emphasis is in the static (declarative) or the active (procedural) part of knowledge. Descriptive representation systems are based on logic theory such as predicate calculus. In predicate calculus the abstract concepts of integration or differentiation operations on numbers (mathematical calculus) are replaced by basic entities (i.e. processes such as vibrating and units such as ships or engines). The actual knowledge representation systems will be explained in the next section.

Based on the aforementioned considerations a more formal picture of the knowledge base is given below:

> A knowledge base consists of declarative and procedural knowledge. The knowledge is expressed on one hand by symbolic descriptions of knowledge parameters and their relationships and on the other hand by procedures for generating problem descriptions and for controlling their solution sequence. Knowledge representation systems are generally based on logic theory such as predicate calculus or procedures.

3.4 Inference Mechanism

The inference mechanism is basically a knowledge control scheme employed to obtain a requested goal. Sometimes it is useful to distinguish between inference and the mechanism within which the inference fits. Examples of inference techniques are pattern matching and statistical methods. Traditionally, inference mechanisms have been founded on either forward chaining or backward chaining or a combination of both.

Forward chaining involves reasoning from data to hypothesis. It is a control procedure that produces new decisions by affirming consequent propositions from inference rules. As new affirmed propositions change the current set of beliefs, additional rules are applied. The rules consists of a condition and an action part. If the condition matches the appropriate parameters in a database then the action is executed.

Backward chaining attempts to find data to prove or reject a hypothesis by regarding it as a goal. To achieve a goal the system first enumerates the appropriate conditional propositions that would be sufficient for goal attainment. In the second step it attempts to achieve or establish the propositions themselves as goals. This means that the overall goal is resolved into a number of subgoals; each subgoal is then further partitioned into more subgoals until a basic premise is reached.

Forward chaining is data dependent whereas backward chaining must be explicitly called by another part of a system. Each technique is a powerful tool and either can be suitable in different applications. Successful systems often employ a mixture of both.

3.5 Types of Expert Systems

Most expert system applications fall into one of the distinct types summarised in Table 1.

Diagnostic expert systems explain why abnormal circumstances are present in a system. Problems of this kind are very common; they include diagnosing a patient's illness, localising a fault in an electronic circuit, and identifying the fault which caused loss of engine power. Diagnostic expert systems relate observed behavioural irregularities with underlying causes using a number of alternative techniques. The most common method is based on acquiring a database with real observations of associations between symptoms and malfunctions. Another technique is based on generating a description of the system behaviour corresponding to all possible candidate faults; then matching the simulated symptoms with real observations. Finally, causal models which describe all the system components and their relationships could provide the basis of the most advanced diagnostic expert systems in the future.

Prediction expert systems infer likely consequences from given situations. Weather and economic forecasts and predictive maintenance schedules are typical examples. Usually a parametric dynamic model is employed. The value of key parameters, appropriate for a given situation, is selected by heuristics. It is often more realistic to produce answers as a series of optional outcomes; these are based on assumptions which can be also chosen by heuristics.

General advice expert systems are used for retrieving information about specific problems. First, the problem is intepreted by heuristics. Then the appropriate information is selected from the knowledge base and presented to the user as advice. Although commonly used in accounts, administration and cost estimates they can be applied in many engineering functions. Design appraisal, based on specific codes or an identified set of first principles, could usefully employ such methods. Advice on what international convention regulations to apply in certain situations could be obtained by interrogating an expert system. Also regular information bulletins could be stored in a form where the user is quickly guided to the appropriate data. In the shipping world such bulletins are newsletters for bunker information, freight rate trends, market movements and so on. To all intents these systems are capable of acting as a library with an efficient librarian, finding the correct data for the user.

Table 1 Categories of expert system applications

Category	Function	Features		General applications		Marine applications
		Problem	System	Dialogue Mode	Real time	
1. Diagnosis	Infer system malfunctions from a set of abnormal findings.	Multiple simultaneous faults. Several possible answers.	Database of associations between symptoms & faults. Simulation, causal models. Filtering of improbable answers.	Medical Electronic Mechanical Software	Electronic Mechanical Software	Fault diagnosis - Machinery - Electrical - Communications 'Performance' deterioration - Engine - Hull - Propeller
2. Prediction	Infer likely consequences of given situations.	No established theory. High number of significant variables. Parameters with variable interactions.	Parametric dynamic models. Generation of a range of answers based on different assumptions.	Weather forecasting. Crop estimations. Economic forecasts. Risk prediction.	Traffic prediction. Military threat prediction. Financial forecasts.	Predictive maintenance. Trading and freight rate predictions.
3. General advice	Infer problem descriptions from specific requests. Apply appropriate rules or select appropriate information.	Large number of rules, constraints, regulations. Variable interpretations of problem description.	Information storage and retrieval. Database management. Interpretation by heuristics.	Administration. Law advice. Accounts. Design assessment. Information communication.		Ship machinery design. International Conventions. Classification requirements. Ship operating costs. Shipping information.
4. Identification	Infer descriptions from observables.	Multi discipline. Different levels of abstraction. Different types of information.	Assignment of symbolic meaning to structure, form, and properties of physical objects or situations.		Vision. Speech understanding. Image analysis. Surveillance	'Intelligent Front Ends' in monitoring, and surveillance systems, navigation, position control.
5. Planning	Generate and evaluate configurations, actions or designs to satisfy given constraints.	Multiple solutions. Concept generation and evaluation. Optimisation of objective function. Qualitative and quantitative constraints.	Generation of object descriptions in various relationships. Prototype plans – monitoring – evaluation and replanning. Continuous reasoning.	Design	Robotics. Communication. Military planning. Resource allocation. Scheduling. Flexible manufacturing.	Voyage planning, Ship and offshore platform design. Maintenance and surveys planning. Business plan.
6. Monitoring	Comparison of observations with key features of an adopted plan.	Evidence for and against possible plan outcomes in the light of new information received or derived.	Hypothesis updating. Probabilistic techniques. Fuzzy logic.	Fiscal management. Project management.	Regulatory control. Nuclear power plants.	Fleet management. Business plan monitoring.
7. Control	Integration of identification, diagnostic, predictive and monitoring functions within an overall control plan.	Dynamic task scheduling. Error recovery. Automatic supervision.	Integration of techniques from all other categories. Selection of control algorithms and parameters. Dependency networks.	Control System design.	Air traffic control. Business management. Missile control. Engineering control. Communication control.	Ship management. Bridge integrated control. Dynamic positioning.

A special category of general advice expert systems is the intelligent front ends that aid operators of complex systems to deal with emergency situations. For example when dealing with a multitude of alarms of large distributed control systems during a process upset. Potentially, intelligent front ends will become part of most simulation or other complex computer programs.

Identification expert systems infer descriptions from observations. Problems are solved by storing knowledge of the structure, form and properties of physical objects describing

the state of a system. This category includes vision models, speech understanding, image analysis and surveillance. Vision and to a lesser degree speech understanding are the most difficult areas of AI research as different types and levels of abstract information are involved.

Planning expert systems generate configurations, actions or designs that satisfy given constraints. A plan is often formulated by connecting the main entities of a problem in various relationships. Heuristics are used to evaluate alternative plans and suggest improvements. Constraints represent usually conflicting criteria, generally incompletely defined, and almost certain to change with time. Heuristics are necessary to re-order priorities according to the prevailing set of constraints. Applications include design, robotics, communication, military planning, resource allocation and manufacturing.

Monitoring expert systems compare observations with system features that seem critical to a successful plan outcome. These critical features are potential flaws in the plan. Thus, the system is looking for conditions which might invalidate the plan or for potential effects which could violate a prescribed constraint. Possible applications exist in a wide range of sophisticated systems such as those employed in nuclear power stations, air traffic control and fiscal management aspects.

Control expert systems have been left to the end as they can incorporate all the other systems. An expert control system governs the overall system behaviour. Control is based on formulating a plan and monitoring its execution to refine details. Identification, diagnostic and predictive functions are linked to the plan monitoring system. Air traffic control, business or ship management and process control are primary examples.

3.6 Features of Viable Expert System Applications

In the previous sections the main areas for expert system application have been identified. Some rules of thumb for choosing the "right" type of application (one with relatively high probability of success) are given in this section.

(i) Problems in which specialized knowledge is needed but do not require common sense.

(ii) Problems in which experts can articulate their knowledge.

(iii) Problems in which there is an agreed vocabulary.

(iv) Problems in which there is agreement between experts (i.e. military problems, government or economic plans, are not good applications).

(v) Problems which are not trivial and have generated general interest.

(vi) Problems in which clear test cases or classical examples can be identified. These expose the essential principles of knowledge and reasoning involved and can be used for incremental development and testing of the knowledge base.

(vii) Problems in which models can be used to produce an early working prototype and simulated data can provide a simplification for noisy real data.

3.7 Assessment of Expert Systems

The assessment of an expert system can be based on the evaluation of its distinguishing features; i.e. expertise, generality and learning. These assessment criteria can be used to characterise a given system's emphasis, as only one feature is usually predominant.

The first obvious criterion for an expert system is its "expertise" in a specialised area (i.e. ability to produce high quality results in minimal time). Two properties, quality and efficiency are implied here. Quality is the ability to solve a problem by applying in-depth knowledge. A difficulty associated with this criterion arises because the range of application is not considered. Some systems handle a limited number of problems very well but cannot solve problems even slightly outside a narrow system specification.

Expert system efficiency is related to the speed of deriving a solution. Equivalent efficiency in human experts is judged by the ability to recognise relevant patterns in a problem specification and to jump quickly to a set of possible solutions. Most of the expert systems that have been built to date rely on algorithms which allow large amounts of ground to be covered in each inferential move. This, however, has a negative effect on system robustness and the ability to explain how results are derived. Furthermore, efficiency must be related to the complexity of the subject to which the system is applied. Problems with a small number of decision points and a few alternatives at each of those points do not require the intervention of an expert or of an expert system.

The second criterion is general problem solving ability. This ability depends primarily on the quality of the symbolic knowledge representation and the reasoning mechanism. Successful systems of this kind can provide some answers at the outer edges of their knowledge even though confidence levels may be low. They also facilitate some degree of interpolation between rules.

The final criterion relates to "learning"—the most advanced "intelligent" aspect of expert systems. The ability to learn, though presently in its infancy, makes a system capable of expanding and refining its own capabilities. An essential requirement before learning is the systems's ability to reason about its own processes. This, in practical systems, is often implemented by tracing back the rules that played a part in a problem solving session. The rules then serve as their own justification. To remove these limitations in reasoning, causal models need to be developed. Reasoning based on fundamental principles is a prerequisite for learning.

Specific research on computer learning has emphasised the general inductive inference methods[5]. A special case of inductive learning is learning from examples. This involves search for common features in examples which can be subsequently used in classification rules or concept descriptions. The general form of inductive learning is based on observation and discovery. This involves experimentation with the problem description, theory formation and testing, and creation of classification criteria. When systems with learning capabilities are realised, then "reformulation" (i.e. ability to learn by viewing a problem from different angles) becomes important.

3.8 Knowledge Acquisition

Knowledge acquisition is the method of obtaining problem solving expertise from some knowledge source and its subsequent encoding into a computer program. Knowledge elicitation from specialists involves the collection of specialised facts, rules of thumb and reasoning procedures in a narrow field of knowledge. The transfer of this information to a program may be done with some degree of automation. Most of the time, a knowledge engineer is required to help the expert to structure the knowledge and to identify the important principles.

An intelligent editing program can substitute the knowledge engineer, particularly when the expert is reasonably conversant with computer programming. The editing program must be user-friendly to enable the expert to comply with the structuring details of the knowledge base.

A number of applications for which expert systems are being developed, contain large volumes of data organised in databases. The absence of established theory and lack of experts

makes these data the main knowledge source. In these cases the expert is substituted by data and the knowledge engineer by an induction program. Many marine technology problems fall into this category making computer induction an important technique in this area.

3.9 Rule Induction from Examples

Rule induction from examples is one of many machine learning techniques which have been investigated in AI research. It is of particular interest to engineers for two reasons. First it is a technique heavily investigated and relatively well developed. Secondly many engineering concepts can be described by a set of positive and negative examples of problem instances. Induction based algorithms are aimed at discovering regularities or underlying relationships in a set of examples. These are used to generate rules that provide decision trees and point to the most significant solution parameters.

Specifically, the induction software packages available today are aimed at producing IF (condition)—THEN (action) rules without reference to the cause for the conditional or action parts. The ID3, INDUCE, HGA and BEANGLE systems are examples of this category.

The induction process is often categorised according to the source of the examples. If the source is an expert, a sequence of examples can be selected to optimise convergence to the desired concept. When the source is the system itself, examples are generated from the knowledge base information; and an expert is then asked to classify them as positive or negative.

3.10 Basic Notation

During the development of expert systems three main elements are frequently used: classes, objects and attributes (Fig. 9). At the top level classes denote the basic problem concepts. Objects then represent particular instances of a class. The object can be thought of as the basic unit of the system. The characteristic properties which can be attached to a class are referred to as attributes. The attribute values are different for each object of a class.

4. KNOWLEDGE REPRESENTATION AND AI SOFTWARE

Knowledge representation systems render knowledge accessible to computers. They are often labelled as descriptive or procedural depending whether the emphasis is in the static or the active part of knowledge. In reality, most systems can be ascribed into a two dimensional space defined by declarative and procedural axes. The systems which are frequently referenced in existing experts systems are the production, the backward chaining and the frame systems, (Fig. 10).

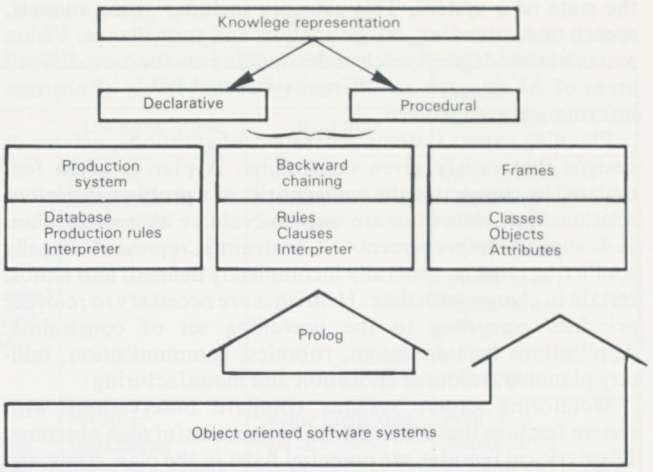


Fig. 10 Knowledge representation systems

4.1 Declarative Systems

In pure declarative systems, it is assumed that knowledge representation can be formulated independently from considerations of the way that knowledge will be used. Consequently these systems consist of two components. A static part based on logic theory such as predicate calculus and an active processor (inference mechanism) which ideally has no representational functions and which is independent of the declarative component.

The classical declarative representational mechanism in AI research is the predicate calculus. Predicate is what can be affirmed as true or existent (ie. all men are mortal). As explained previously predicate calculus is a method of manipulating logically basic entities. Knowledge is represented by translating information into formulae of predicate logic. These formulae are added in the knowledge base as axioms. Inferences are formulae deduced from the axioms by inference rules. An example illustrating some details of predicate calculus is given in Appendix 1.

The solution approach in predicate calculus is that the goal state is expressed by a formula and is regarded as a theorem which is to be deduced from the axioms by the inference mechanism.

Some of the advantages of predicate calculus are that the syntax and formal interpretation are well defined, there are clear inference rules and the knowledge base is modular. A major disadvantage is that it does not contain any information about how to use knowledge. As a result the necessary effort to derive a theorem is impractical, even for simple problems. Goal-orientated heuristics have been introduced in some applications to control the inference processes. Addition of heuristics of this kind increase the efficiency of inference at the expense of the system's simplicity and homogeneity.

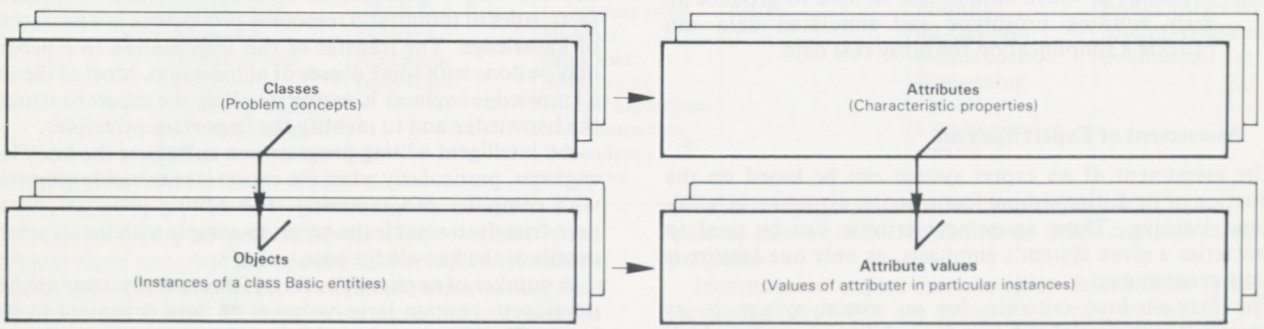


Fig. 9 Expert system elements

Research to improve the restrictive expressive power of predicate calculus is currently being undertaken. Many investigations are concentrating on advanced forms of logic (non-monotonic) and on integrating predicate calculus with other representations (e.g. loglisp). One promising approach is the concept of "global representation" mechanism. In this approach, predicate calculus is only appropriate for representing local knowledge. The global scheme realises the connection between many local points.

The other main logic based representations, perhaps with a lesser impact in general AI developments, is the semantic networks. Direct representation and decision trees are also used for certain applications.

4.2 Procedural Representation

In procedural representation, emphasis is placed in the knowledge which is put into the procedures rather than in a static factual part. Furthermore, knowing how to apply knowledge for a particular purpose is the essential characteristic of the system.

There are several distinct characteristics in procedural representation systems. The static knowledge base is relatively small. It does not contain "axioms" but just simple so-called "assertions" which represent reference conditions likely to be changed or deleted at any time. General knowledge and inference rules are represented by specialized goal orientated procedures that are activated when needed. For example a procedure $X \wedge Y \rightarrow Z$ (to prove Z first prove X and then Y) would be activated when Z is to be shown. This would yield two new goals, for X and Y, for which other procedures will be triggered.

Procedures can be activated by other procedures or data. Data driven activation is normally associated with special procedures commonly referred to as Demons. Demons watch to see whether particular data are entered in the knowledge base, and then initiate some action.

An advantage of procedural representation is that control knowledge supports straightforward processing of information for particular purposes. The expressive power of procedural systems is comprehensive; any other scheme can be implemented by a procedural one. Drawbacks include loss of transparency in comparison to the declarative systems: knowledge can be attributed to a procedure as a whole and not to particular separate elements. Complex interaction between procedures creates the problem that adding or removing a procedure can lead to unexpected side effects.

The extended expressive power of procedural systems is generally accompanied by comprehensive inference schemes. Most of these can be characterised by the notion of "default assumption". They are reducible to the scheme "If A (precondition) is valid and there is no counter-evidence for B, then assume B". Such rules are especially useful for problems with incomplete knowledge.

4.3 Forward Production Systems

Forward production systems can be realised both procedurally and declaratively. They consist of three main components as shown in Fig. 11; a database, a set of production rules and an interpreter. The database contains the reference knowledge about a particular subject. Any changes in the database are monitored by the interpreter. The production rules contain specific knowledge about what additional facts can be assumed if certain conditions are satisfied (i.e. when changes in the database match with the condition of the rules). The action part of the production rules may represent these facts statically. In this case it is the interpreter which adds them to the database. Alternatively the production rules can include active procedures that automatically perform the necessary operations on the database. New facts added to the database may trigger other

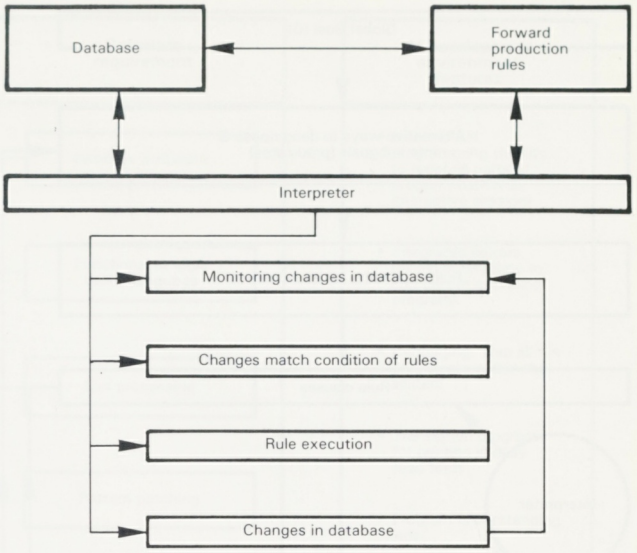


Fig. 11 Forward Production System

production rules which create more new facts. The database is the variable part of the system. The production rules and the interpreter are constant.

Classical production systems have the desirable property of modularity; production rules can be added or deleted without unexpected side effects. The reason is that procedures are initiated only by data and not by other procedures. Production rules, therefore, can be particularly suited for domains described by a large number of independent heuristics. The previously described expert system RI for configuring DEC VAX computers and up to a point DENDRAL are based on production rules.

The drawback of production systems is that they do not contain control knowledge. As with declarative systems the consequences are twofold. First, inefficiency occurs because all the condition parts of all production rules are tested before a rule is activated. Second, inference generation is totally unguided; every iteration depends on all the system variables. In order to alleviate the first problem, structural improvements of the database have been proposed. In order to ameliorate the second problem, control procedures can be applied based on a pre-specified agenda. Another possibility is to explicitly control the sequence of execution. Production rules can, for example, deposit additional control signs in the database which will trigger certain other rules in subsequent cycles.

4.4 Backward Chaining System

The backward chaining rule system is the basis of the Prolog programming language. In comparison to the production system backward chaining is not data dependent and consequently consists only of two components; a set of "predicates" and the interpreter, (Fig. 12). Each predicate consists of rules and facts arranged in a specified sequence. The rules are headed by the definition of a goal and contain a set of conditions or clauses which must be satisfied to reach that goal. Various types of clauses can be employed ranging from pattern matching (similar to production rules) to calls of other predicates or some procedural code. When a clause is failed the interpreter will backtrack to the previous successful clause. It will then try an alternative set of clauses. If a rule is failed the interpreter will backtrack to an alternative subgoal.

Again controlling the way the rules are applied is not specified by control knowledge. Top to bottom evaluation and chronological backtracking are normally employed. The declarative system benefits and disadvantages are applicable. MYCIN is based on the backward chaining system.

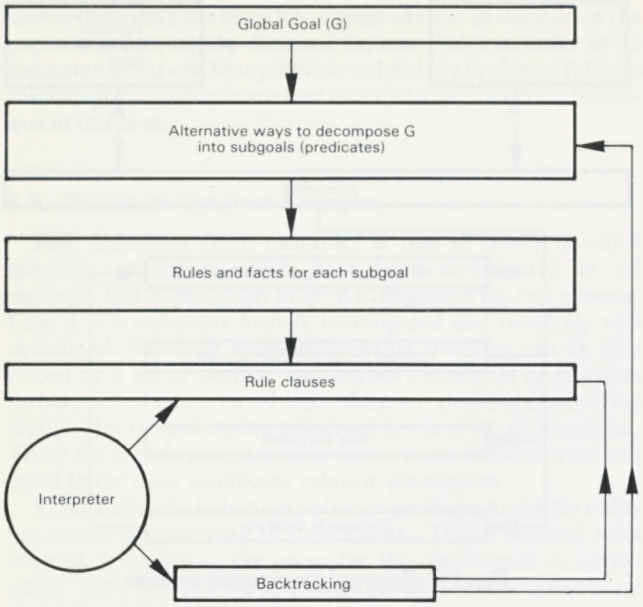


Fig. 12 Backward Chaining System

4.5 Frame Systems

Frames provide the framework for expanding and improving the possibilities offered by the other systems. Frames were introduced into the AI research in 1975[6]. The theory is based on concepts of analogy and inheritence and can be clearly summarised by the following principle: "When one encounters a new situation, one selects from memory a structure called a frame. This is a remembered framework to be adapted to fit reality as necessary".

Knowledge is represented by descriptions of stereotype situations containing information about their common properties. Some parts of the descriptions are always applicable, others are allowed to have a certain range of variation.

The frame system is composed of a collection of related frames. Each frame is normally composed of two components: a global frame and a set of slots (attributes) containing characteristic properties, (Fig. 13). The global frame can be viewed as a fixed data structure for representing a stereotype situation like a living room, the engine room of a ship, or surveying a ship. It contains invariant knowledge (slots) which is valid for all situations to which the global frame is applicable. As an example, the global frame for a "ship's engine room" contains slots for the main propulsion system, generators and auxiliary machinery. Then, every "engine room" will be assumed to have these components. The value of these attributes is filled when the frame is activated. Initially "default" assignments can be used.

Each slot contains a property which can be defined by other frames. This means that in the "engine room" example, the "propulsion system" slot is defined by another frame specifying the number of propulsion units and the type. A "diesel engine" frame will then include attributes such as the injection system, the turbocharger, and the number of cylinders.

The frames in a system are linked by an information retrieval network. When a proposed frame cannot be made to fit reality this network provides a replacement frame.

The principal operations which are associated with frames are instantiation and activation. First, the frame that fits best a new situation is activated. The attributes of this frame are then filled with specific details during the instantiation process. For example, the "diesel engine" frame for a specific ship will be filled with the engine make: SBIW, the injector system: electronic, and turbocharger: variable geometry. During instantiation heuristics can be used to identify the values of the attributes. If a selected frame and the actual situation do not match adequately, a new frame is looked for. The original

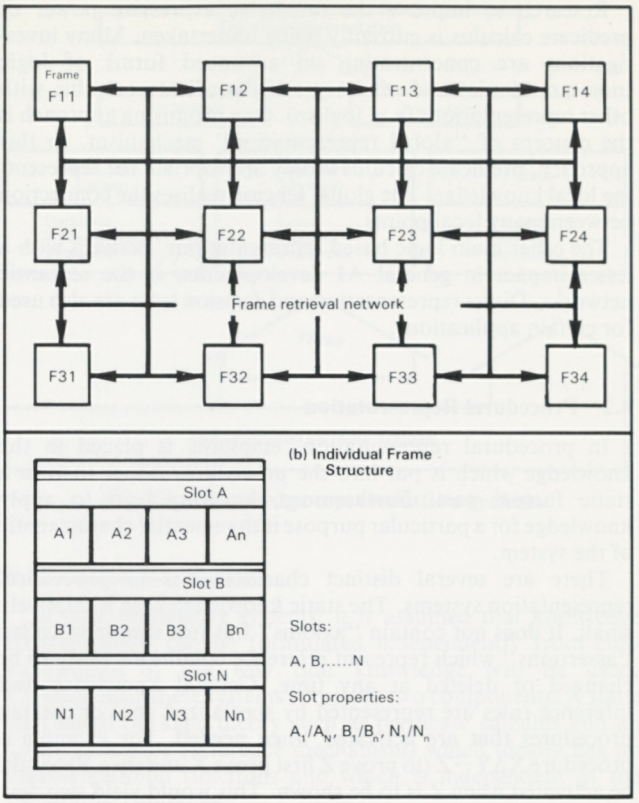


Fig. 13 Frame representation system

frame may contain hints as to what type of other frame can be investigated (i.e. more general, more specialised, etc.). The slot values of the original frame can be inherited by the new one.

A special kind of frame is the so called "scripts". Scripts were developed to represent stereotyped sequences of actions and events. Scripts are more appropriate when dealing with dynamic environments. A sequence of frames gives a description of changes with time (useful in applications such as weather forecasting or predictive maintenance).

To combine advantages of both the declarative and procedural systems, the knowledge concerning the representational function of a frame can be stored declaratively and the control knowledge in a procedural way. Procedures will then activate frames when particular situations are recognised.

4.6 AI Languages and their Environments

In introducing the AI languages, the requirements of AI problems and the implication of these requirements for the language are first examined, (Fig. 14).

Current AI programming is basically concerned with the simulation of human intelligent behaviour through symbol manipulation. Symbols represent the knowledge units which can be used to build complex knowledge structures. The solution sequence of many AI problems involves the generation of large numbers of intermediate solution data. This is facilitated by the use of a functional language, (Fig. 15). At each stage the intermediate data are assessed by pattern matching techniques or heuristics. The generation of intermediate problem states involves search for applicable knowledge, or for alternative solution paths. Search in a complex solution space often leads to what is termed "combinatorial explosion" (exponentially increasing number of choices). Although this can be resolved by the introduction of heuristics, automatic memory management is important. This requirement is more dominant when the body of heuristics grows, and search for relevant heuristics requires extra heuristics to control this additional search space. Control knowledge provides the

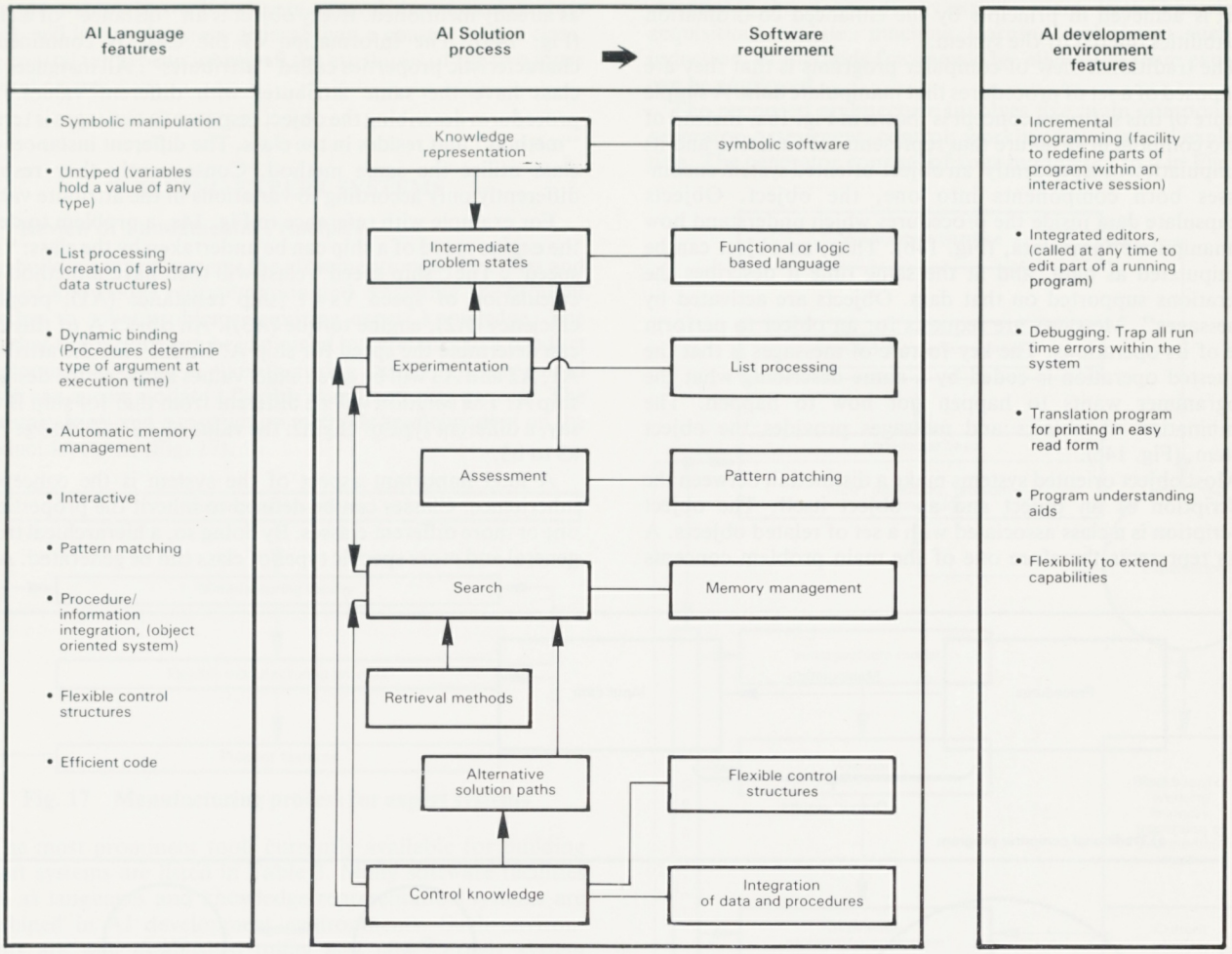


Fig. 14 Requirements for AI languages

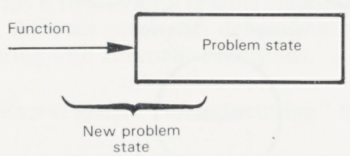


Fig. 15 Functional programming

management of both search and assessment and requires flexible control structures in the programming language.

The flexibility requirement for the language is further emphasised by the experimental nature of the solution process in AI problems. List processing, untyped variables and dynamic binding are some of the features which have been introduced for this purpose in AI languages. Many of the features which are summarised in Fig. 14 are available in the main AI languages LISP, PROLOG and POPII.

A brief description of some distinct features in LISP, PROLOG and POPII is given in Table 2. LISP was developed as a functional language and provides the highest level in self-manipulation. This means that everything is coded in LISP, no compilers are necessary, and building other software layers (for example a reasoning module) on top of LISP is very easy. POPII is similar to LISP though perhaps weaker in its functional capabilities. It has a much simpler and conventional syntax which was the objective for its development. Finally PROLOG is different in as far as it is a logic programming language. The control mechanism in PROLOG is based on backward chaining. The practical versions of all languages today have veered from their initial pure declarative or functional nature. Different means have been devised to combine declarative descriptions and functional control.

Table 2 Main characteristics of AI languages

Property	LISP	POPII	PROLOG
1. Symbolic software	√	√	√
2. Flexible representation			
(i) List data structures	√	√	√
(ii) Dynamic binding	√	√	√
(iii) Untyped variables	√	√	√
3. Functional language	√	(√)	–
4. Function generation at run time.	√	(√)	–
5. Logic programming	–	–	√
6. Self-manipulation	√	√	√
7. Conventional syntax	–	√	(√)

One characteristic aspect of AI programming is that the language is often only used as part of a development environment. "The task of many AI problems is not one of coding up a solution but of exploring the problem and its possible solutions". To satisfy this requirement, development environments have been constructed that support the evolution of a program as the problem understanding develops through experimentation. Some of the important characteristics of these environments are listed in Fig. 14. Simpler software packages aimed at assisting users to build expert systems for specific applications are termed expert shells.

4.7 Object Oriented Programming

Object oriented systems are extensively used in AI programming and offer increased power in coding complex processes.

This is achieved in principle by the enhanced co-ordination capabilities offered by the system.

The traditional view of computer programs is that they are composed of a set of procedures that manipulate data. A simple picture of this software concept is shown in Fig. 16a. Instead of a two component structure that represents information and its manipulation independently, an object-oriented system encompasses both components into one, the object. Objects encapsulate data inside the procedures which understand how to manipulate these data, (Fig. 14b). Thus, an object can be manipulated as data, and at the same time it describes the operations supported on that data. Objects are activated by "messages". Messages are requests for an object to perform one of its operations. The key feature of messages is that the requested operation is coded by a name describing what the programmer wants to happen not how to happen. The combination of objects and messages provides the object system, (Fig. 14c).

Most object oriented systems make a distinction between the description of an object and an object itself. The object description is a class associated with a set of related objects. A class represents therefore one of the main problem concepts as already mentioned. Every object is an "instance" of a class, (Fig. 14d). The information of the class is contained in characteristic properties called "attributes". All instances of a class have the same attributes with different values. The procedures describing the object response to messages is termed "method" and resides in the class. The different instances of a class utilise the same method. Consequently they respond differently only according to variations in the attribute values.

For example with reference to Fig. 14c, a problem to derive the engine speed of a ship can be undertaken by the class: "ship speed". The "ship speed" class will then have a method (i.e. calculation of speed Vs = f [ship resistance (A1), propeller efficiency (A2), engine torque (A3)]. An object A of this class can determine the speed for ship A. In this case the attributes A1, A2 and A3 will be given exact values knowing the design of ship A. The solution will be different from that for ship B with say, a different type of engine: the value of A3 will change from a3 to b3.

A final important aspect of the system is the concept of inheritence. Classes can be defined to inherit the properties of one or more different classes. By doing so, a hierarchical tree of general and more specific types of class can be generated. As an

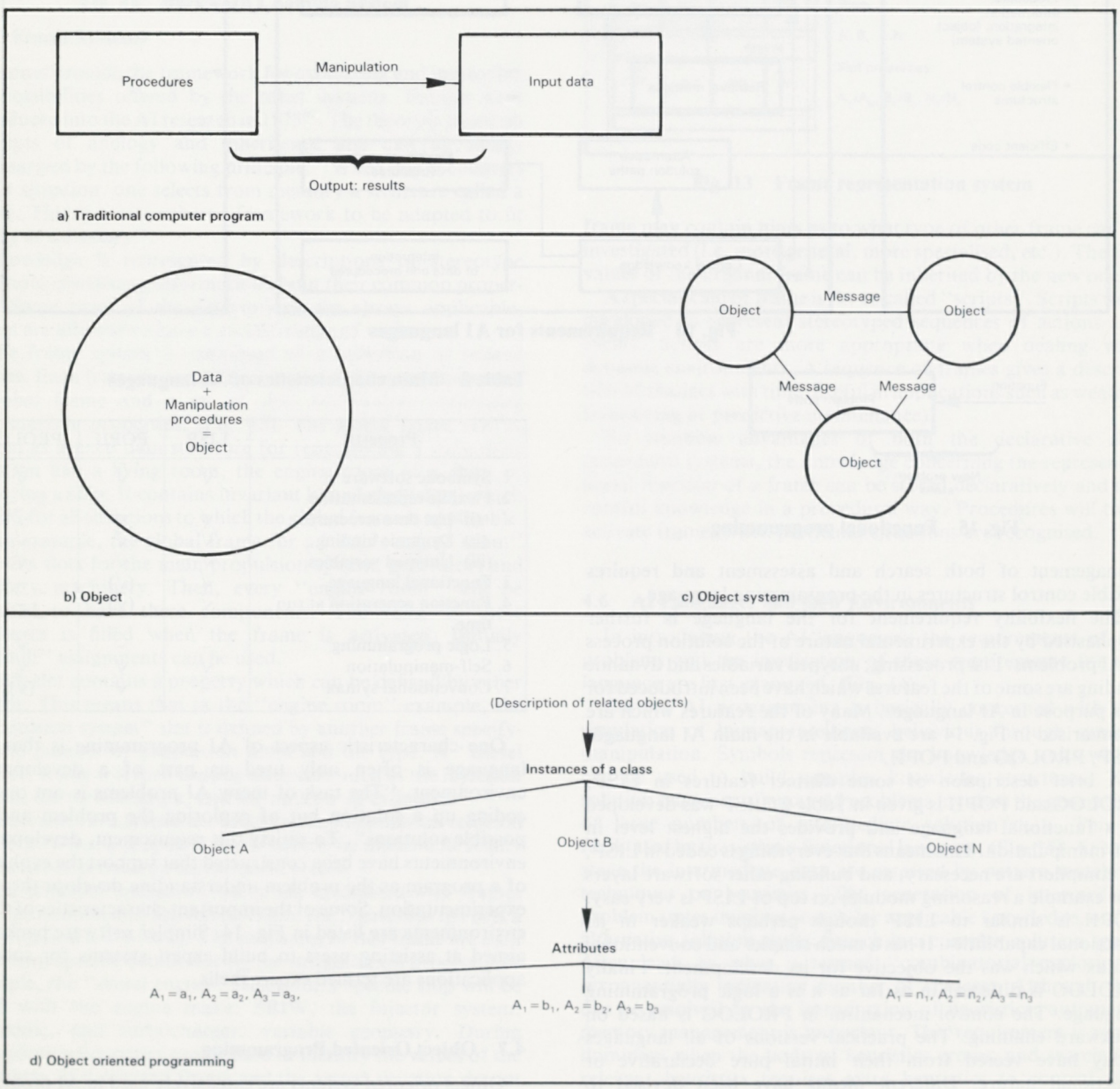


Fig. 16 Description of object-oriented systems

example a ship class will be more general than a tanker class which will in turn be more general than a coastal tanker class. The coastal tanker can inherit all the attributes of the two more general classes.

5. BUILDING EXPERT SYSTEMS

5.1 Review of Fundamental Principles

In building expert systems the aforementioned principles and tools of knowledge representation and reasoning are brought together to solve problems requiring expert knowledge. The way that this is done can be explained by reference to a product development process. A manufacturing facility is first required which can accommodate a flexible manufacturing process. The necessary tools and construction methods are dependent on the product features, (Fig. 17).

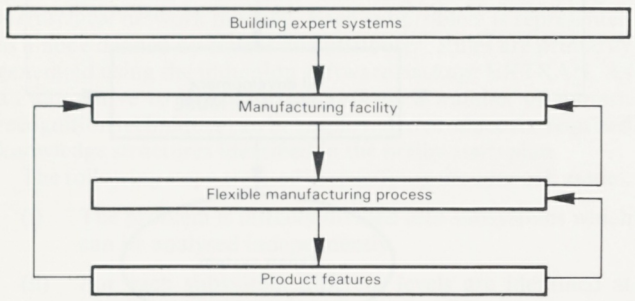


Fig. 17 Manufacturing process for expert systems

The most prominent tools currently available for building expert systems are listed in Table 3. Many software facilities such as languages and knowledge representation systems are combined in AI development environments. Such environments are well established today and new "expert system builders" are under development. A fundamental aim of all these systems is to provide a flexible manufacturing process for exploring different ways of defining a problem and for experimenting with alternative solutions.

Table 3 Expert system "manufacturing" tools

1. Knowledge acquisition	Elicitation from experts Induction from examples General inductive inference.
2. AI Software	
2.1 AI languages 2.2 AI language environments 2.3 Algorithmic languages 2.4 Programming method 2.5 Knowledge representations 2.6 Reasoning modules 2.7 Control structures 2.8 Explanation routines	LISP, Prolog, POP II ART, KEY, MUSE, POPLOG. . . FORTAN, C, PASCAL . . . Object oriented Forward production, Backward chaining, Frame systems. Forward/Backward chaining rules. Blackboard system, Databases. Causal models. Dependency networks
3. AI Hardware	
3.1 Development computer 3.2 Target machine 3.3 Parallel processing	Symbolics, Sun, Explorer . . . PC, VAX, MICRO's . . .

A comprehensive manufacturing process for building expert systems is depicted in Fig. 18. It contains a large number of features to demonstrate what are the possibilities rather than what will be found in a typical system. The man/machine interface, already described as the input/output module, is essential to the success of any expert system. In the knowledge acquisition module, machine learning techniques such as induction, or methods for knowledge elicitation from experts, can be employed.

The proposed architecture involves five main components; generator, assessment, control, working memory and explanation. The generator consists of four modules (1 to 4 in Fig. 18)

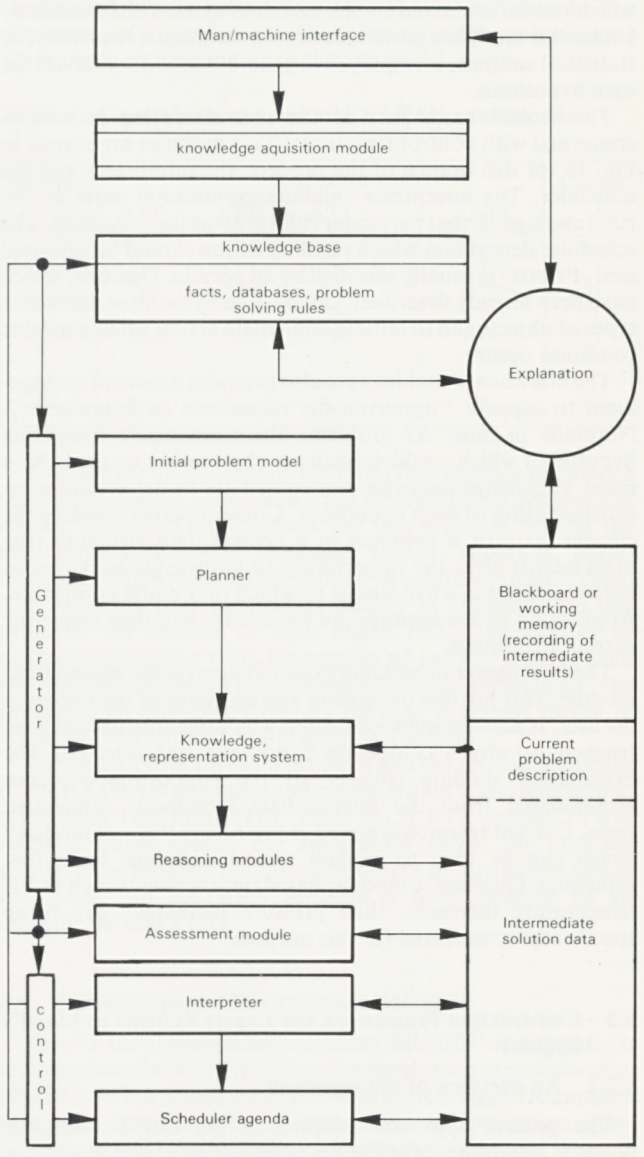


Fig. 18 'Manufacturing process' for expert systems

which operate on the knowledge base to produce intermediate or "experimental" solutions. In module 1, the initial problem model is defined in terms of basic concepts. For example, in a diagnostic problem the fundamental concepts are the possible illnesses or faults and the associated symptoms or measured changes from reference values. The second module is the planner which describes the overall strategy that the system will pursue against the current problem. In the majority of cases the plan involves a Hypothesis-Evaluation-Refinement approach. The details of the plan depend on the problem complexity, the reliability of the input information, and the extent of available knowledge on the subject. Having established an initial problem definition and plan for tackling it, the knowledge representation system can be selected, (module 3). Here the problem can be divided into subproblems, and the main knowledge building blocks (classes, objects, attributes) within each subproblem are identified. The application of modules 1 to

3 generates the current problem description which is recorded in a working memory. A special working memory arrangement is the so called "blackboard". The blackboard provides a means of recording all the intermediate problem descriptions and solutions. The intermediate solutions are produced by the reasoning module 4 which consists of production and/or backward chaining rule systems.

The intermediate solutions can be regarded as hypotheses which can be evaluated by the certainty assessment module 5. Under this module a pattern matching technique, heuristics, or statistical analysis, is employed to generate confidence levels for each hypothesis.

The second main part of the manufacturing process is concerned with control structures. Two modules are shown in Fig. 18 for this branch of the process: the interpreter and the scheduler. The interpreter validates conditional parts of the rules and signals that particular rules are waiting execution. The scheduler determines which pending action should be executed next. Priority is usually specified by an agenda. Demons, which have been already described, can be used to monitor particular types of objects and to initiate immediate action when a specific condition occurs.

The blackboard architecture also provides a control arrangement to support "opportunistic refinement of hypotheses". Normally in most AI problems there are many competing hypotheses which could explain an observation or goal. Also many knowledge packages can contribute to the evolution or substantiation of each hypothesis. Consequently recording the current state of a problem in a central data structure (the blackboard) gives the opportunity to knowledge packages to note that there is a hypothesis to which they could contribute. Application of the appropriate knowledge will then refine the current hypothesis.

The final aspect in building expert systems is the explanation module. This justifies the actions and decisions of the system to the user. It answers questions about why some conclusions were reached or why a competing hypothesis was rejected. The explanation module collects all the supporting evidence accumulated from the intermediate hypothesis refinement steps. Current research is aimed at producing "causal models" which can be used to explain system decisions from first principles. Qualitative models, based on statements such as "If temperature increases, then pressure increases" are being specifically investigated for this purpose.

5.2 Construction Framework for Expert Systems at Lloyd's Register

5.2.1 An overview of the approach

The general approach adopted in the Lloyd's Register research programme for the development of expert systems is outlined in Fig. 19. The knowledge acquisition phase incorporates both knowledge elicitation as well as computer induction from examples. The approach is based on a two stage prototyping arrangement aided by an Information Analysis Expert System (IAES). The underlying concept introduced in this architecture is that of "Prototype Formulation and Refinement". Producing a prototype working model is a common approach in engineering developments. In constructing expert systems this becomes almost essential due to the complexity of the problems and the experimental type of solutions. Also human experts find it easier to criticise a working system than say what is needed at the initial stages of development. The two stage approach satisfies the flexibility and experimentation requirements and gives some modularity in the architecture. Furthermore the knowledge base can be incrementally developed and tested.

The first stage of the construction process is concerned with a "prototype rule based" system. This first prototype contains rules, typically arranged in a decision tree format, to provide

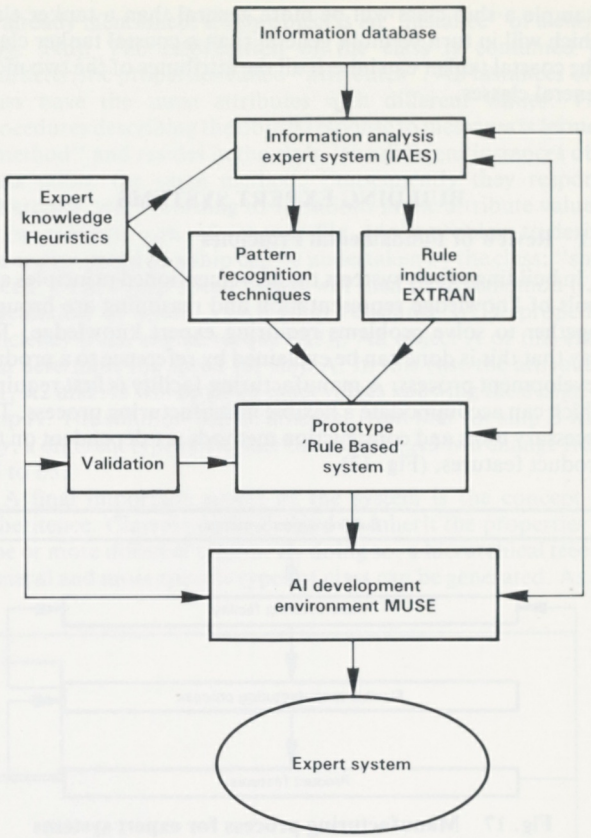


Fig. 19 Framework for building expert systems in the LR research program

solutions for a simplified model of a problem. The prototype rule based system is much simpler compared to the final expert system. Validation and testing of the rules by experts can be consequently undertaken with relative ease, particularly as it is easier to find exceptions to the rules. With reference to the previous section, the prototype "rule based" system is based on the initial model and the planner.

The second stage of development involves the selection and implementation of a knowledge representation system and a control strategy in the AI development environment, MUSE. MUSE is an integrated set of tools for developing real-time artificial intelligence applications. It provides a range of knowledge representation languages to access a wide range of applications and to cater for development flexibility. Within MUSE the second stage prototypes are being developed. These are also linked to the IAES in a manner that provides the second prototype refinement loop.

5.2.2 Information Analysis Expert System: IAES

The majority of marine applications for which expert systems are being developed contain large volumes of data organised in databases. The traditional research process in these circumstances is to manually select the relevant information from the database, specify a model in suitable terms, "solve" the problem then compare the "fit" against solution criteria. This process forms a prototype working model which is subsequently subjected to the eternal loop of testing-evaluate-refine until the solution criteria are satisfied. This is both inefficient and time-consuming, especially when there is either a large volume of data or a large number of models to be tested.

To overcome this difficulty, recourse is made to the information analysis expert system IAES[7]. IAES controls the extraction of information from the database according to the "initial problem model" defined interactively by the user. The first function of IAES is to provide a software link between a

database (with all the available information on the subject) and the expert system development tools.

To assist in defining the initial problem model IAES prompts the user to answer what is the type of the problem (i.e. diagnostic, predictive, planning, and so on). A list of the main problem concepts is then established interactively. Advice on possible solution methods (module 2 of Fig. 18) is the output of IAES at this stage. Following the selection of an initial plan, the problem is resolved into subproblems and the appropriate classes and attributes are defined. A specific IAES database (Fig. 19) is then produced. This reflects the partitioning details of the problem and the data organisation under the appropriate classes and attributes.

5.2.3 IAES hierarchical network model

The next function of IAES is to facilitate the automatic generation of rules or other knowledge structures using a hierarchical network model[8]. Each subproblem is represented as a node defined by classes and attributes. Rules are primarily generated using the induction software package EXTRAN. As an alternative to the induction process a number of pattern recognition techniques can be employed to produce the required knowledge structures identified in the preliminary plan.

The following steps are used in specifying the network model:

(i) The problem is initially divided into subsystems which can be analysed independently.

(ii) For each subsystem different levels are identified at which information contributing to different aspects of the solution sequence is grouped together.

At each level the relevant information is distributed into a number of nodes which represent the objects which are being considered within each subsystem.

(iii) The first level of analysis generates the initial hypotheses.

(iv) In the subsequent levels the effects of the initial hypotheses on pertinent problem concepts is considered. The consequences of a given set of hypotheses on dependent physical processes, and the second order (cascade) interaction between subsystems, are examples of aspects considered at two different levels. In another level, the pattern of events over time can be compared with anticipated trends.

5.3 Rule Induction EXTRAN (Expert Translator)

EXTRAN is a FORTRAN-based software package for building expert systems (expert shell)[9]. It contains an inductive learning module, which induces "If-Then" rules from examples. The induction process is based on the ID3 algorithm adapted to additionally cater for numerical values[10]. The ID3 algorithm works as follows:

(1) It selects a random subset of the database.

(ii) Applies the CLS algorithm to form a classification rule.

(iii) Scans the entire database to find exceptions to the rule.

(iv) If there are exceptions, it includes some of them in the considered subset and repeats step (ii).

The CLS algorithm repeatedly partitions data according to the variable with the greatest discriminatory power. In EXTRAN a theoretical parameter of entropy is used for this purpose. ID3 is suitable for reliable data such as those obtained from experiments. It precludes comparing qualitative variables which means that numerical discriptors must be defined for the analysis.

An EXTRAN problem is defined by a set of examples (specific cases) which are in effect equivalent to a set of equations in a deterministic model. In the examples, factors that influence the problem (attributes) are linked to a range of possible outcomes or solution parameters (classes). In comparison to the general AI notation an EXTRAN class has a similar meaning to an object. For a problem with M examples, N attributes ($ATT_1 \ldots ATT_N$) and L classes ($C_1 \ldots C_L$), an example file can be represented by the matrix structure shown in Table 4. The element a_{ijk} of such a matrix is the value of the ith attribute in the jth example corresponding to the kth class.

Table 4 General structure of an EXTRAN example file

Example	Attributes					Classes
	ATT_1	ATT_2	ATT_3	...	ATT_N	
1	a_{111}	a_{211}	a_{311}	...	a_{N11}	c_1
2	a_{121}	a_{221}	a_{321}	...	a_{N21}	c_1
3	a_{131}	a_{231}	a_{331}	...	a_{N31}	c_1
4	a_{112}	a_{212}	a_{312}	...	a_{N12}	c_2
.	.	.	.	...	.	.
.	.	.	.	...	.	.
M	a_{11L}	a_{21L}	a_{31L}	...	a_{N1L}	c_L

To illustrate the concept of EXTRAN attributes and classes a simple problem is considered; that of identifying geometrical shapes. The EXTRAN classes for this problem will be the alternative shapes (i.e. rectangle, square, rhombus, parallelogram). The attributes are properties pertinent to each class. The following four parameters qualify as attributes for this problem: the number of right angles (RA), the number of adjacent equal sides (ES), the number of pairs of parallel sides (PS) and the number of pairs of equal opposite angles (EA). The problem can then be defined by the four examples shown in Table 5a. The induced rule is given in Table 5b.

The overall structure of a problem and the inter-dependency of the EXTRAN attributes and classes within it are described in a Problem Text File (PTF), Table 5c. A PTF consists of five sections which specify the application name; the problem name(s); the problem definition(s); details of attributes; details of classes. An EXTRAN problem is fully specified by an example file and a PTF.

5.4 AI Development Environment (MUSE)

The AI development environment MUSE[11] is currently a main tool available in the Society for developing expert systems. MUSE is an integrated set of software tools designed to support prototype development of experimental AI applications particularly in real-time domains. A key feature of MUSE is that it provides a mechanism for packaging up prototype solutions and delivering them on a specified target machine[11].

The main MUSE components are summarised in Fig. 20. Poptalk, FUSE and the Rule systems are the main subdivisions[12].

Poptalk is the MUSE main AI language for constructing all the procedural code and for directly assessing the object system. It is an object oriented language based on POPII [13] and the Smalltalk object programming[14]. The main facilities in Poptalk (Fig. 20) are the control structures, data structures, variables and input/output channels[15]. These are direct equivalents of POPII functions.

Poptalk is an untype language (i.e. variables can hold a value of any type). A number of variables which are built-in to the language are listed under the heading of data structures in Fig. 20. One of the important data structures is the list; the way lists are defined and the basic operations on lists are explained in Appendix 2.1. Control structures are formulated using "Functions", "Loops" and "Conditionals". Functions control the

Table 5 Typical EXTRAN problem details

5(a) Problem definition (Example file)

	EXTRAN Attributes				EXTRAN Classes
	RA	ES	PS	EA	
Examples	4	4	2	2	square
	4	0	2	2	rectangle
	0	0	2	2	parallelogram
	0	4	2	2	rhombus

5(b) Induced rule

[RA] :	First consider RA
<2 : [ES] :	If it is less than 2, then consider ES
<2 : PALLGRAM	If ES is less than 2 then parallelogram
⩾2 : RHOMBUS	If ES is greater than or equal to 2 then rhombus
⩾2 : [ES] :	If RA is greater than or equal to 2 then consider ES
<2 : RECT	If ES is less than 2 then rectangle
⩾2 : SQUARE	If ES is greater or equal to 2 then square

5(c) General structure of an EXTRAN problem text file (PTF)

Section 1: **Application Title**
Geometric shapes

Section 2: **Problem Names**
EXP_1 (only one subproblem is considered in the example)

Section 3: **Problem Definitions**
EXP_1
{ RA, ES, PS, EA } ← Attribute names
{ rectangle, square, rhombus, parallelogram } ← classes

Section 4: **Attribute Definitions**
RA: Number of right angles
ES: Number of adjacent equal sides
PS: Number of pairs of parallel sides
EA: Number of pairs of equal opposite angles.

Section 5: **Class Definitions**
rectangle is a geometrical shape
:
:

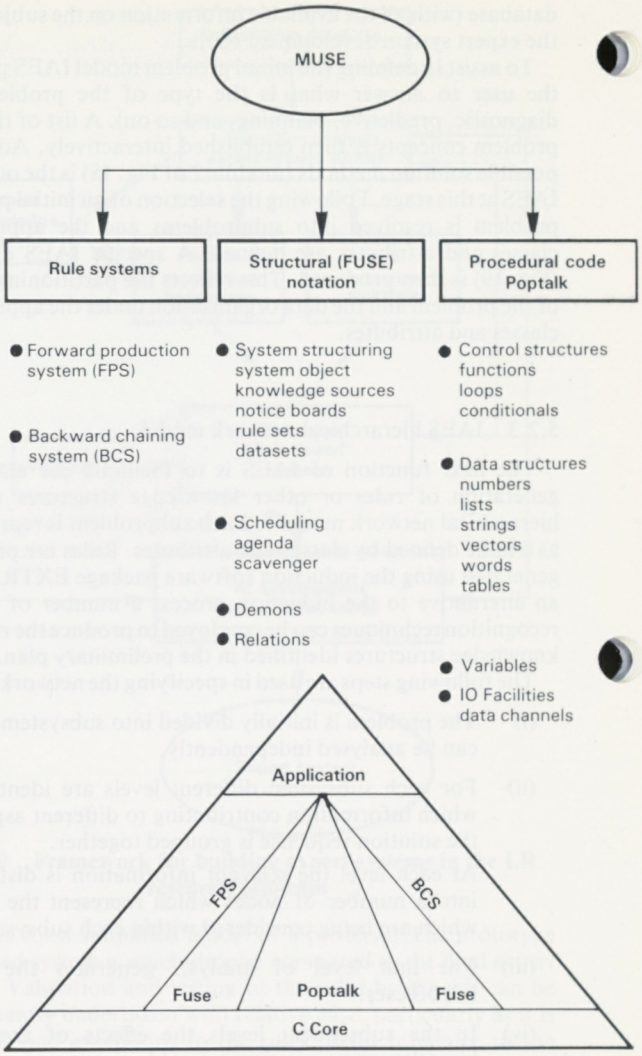


Fig. 20 MUSE components.

execution of a Poptalk program and assist in structuring it. Some details of functions are given in Appendix 2.2.

Poptalk also provides a data capture facility consisting of a series of data channels. These channels can be linked to physical data sources such as sensors and deliver current values of parameters to the system.

The rules system of MUSE consists of a Forward Production System (FPS) and a Backward Chaining System (BCS). The principles of the production representation system described previously are also applicable here. Specifically the MUSE FPS implements an OPS[16] type "match, resolve, execute" production cycle. The FPS is a collection of rules in the form "if the condition is true then execute the action"

The details of the rules as specified in the MUSE FPS system are described in Fig. 21. The condition part consists of a number of clauses. Each clause defines the conditions to be met before the rule can be executed (for example the constraints on the values of certain attributes). Constraints can specify fixed values for attributes or bind attributes on variables. A clause can also request a Poptalk test. The rule actions are simpler than the conditions. They produce changes in the database or initiate the creation, modification or deletion of objects. An example of an FPS rule to detect a match between a hypothesis and a fault is given in Appendix 2.3.

The other rule language used within MUSE is the BCS system. This is very similar in style and operation to Prolog. The general characteristics of backward chaining representations,

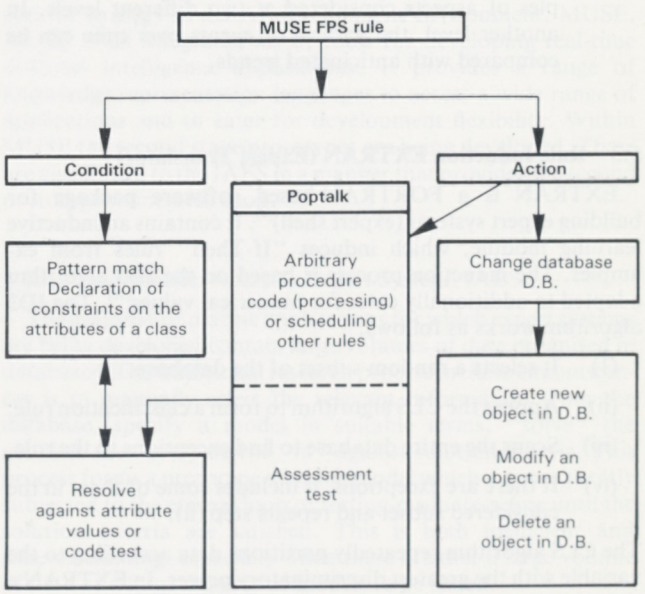


Fig. 21 MUSE forward production system rules.

previously described, are also applicable in MUSE. Thus, the BCS rule base contains statements of relationships between problem concepts in the form:

X is true,
if X1, X2, X3 . . . . . are true
or
if Y1, Y2, Y3 . . . . . are true.

The details of the MUSE BCS rules are illustrated in Fig. 22. The BCS program contains predicates which represent goals and are distinguished by having a unique name and a number of arguments. Each predicate consists of a collection of rules and facts. The rules are headed by a goal or conclusion and contain a set of clauses. The various clause types shown in Fig. 22 indicate requirements for a pattern match, a call to other predicates, or a call to arbitrary pieces of Pop code. Controlling the way that BCS applies the various rules or searches for relationships is not as explicit as in procedural languages. Exhaustive evaluation and chronological backtracking are the basic methods involved. To increase efficiency, some control is possible using the built-in predicate "cut". Cut deletes choice points that can no longer contribute to the solution of a particular problem.

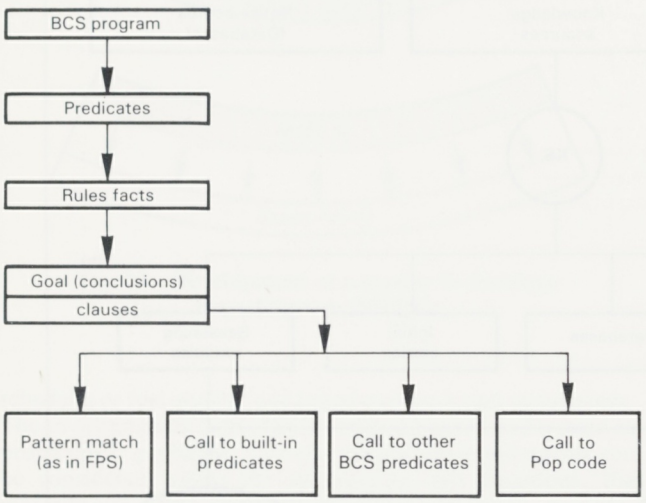


Fig. 22 MUSE BCS rule form.

To demonstrate the structure of the BCS rule an example is given in Appendix 2.4. The BCS rule checks the symptoms of a given fault and gives a certainty factor[15].

As indicated in Fig. 20 the third main element of MUSE is FUSE. This is an intermediate layer providing many of the structures and services necessary in the construction of advanced AI applications. FUSE components include demons, relations and facilities for system structuring and scheduling, (Fig. 20).

The function of demons has been already described. In MUSE, demons are essentially functions watching for the creation of instances of a class, or for changes to the attributes of an instance. A number of different kinds of demon can be declared. "Creation" demons are executed after an instance of a class has been created. The type "post-update" is executed after a particular attribute it has been monitoring has been updated with a new value. A variant of this type is the "multiple" demon which monitors more than one attribute simultaneously.

In MUSE, relationships between objects are specified by special objects called "relations". The rest of the FUSE structuring and scheduling facilities will be described in the MUSE architecture.

5.5 Setting up an Application in MUSE

The basic structure of any MUSE application is a set of reasoning modules termed "knowledge sources" which communicate by shared access to particular databases. Both the "knowledge sources" and the databases can be reached from the "system object" which represents the whole application[11].

The system object is an internally defined class which in MUSE is called schema. As such it contains a number of built-in attributes (slots). The slots of the system object which are useful in structuring an application are the "knowledge sources", the "notice boards", the "schemas" and the "libraries", (Fig. 23).

Knowledge sources are primary structural units and are internally defined by the schema KS. The declaration of a knowledge source includes a number of predefined slots summarised in Fig. 23. The basic structure of a knowledge source consists of a database and one or more rule systems. The rule system consists of a set of rules and a local database.

In the simplest form, knowledge sources can be regarded as databases. Such a knowledge source is then termed a "notice board" and is employed as a communication channel. All production rules monitor such global databases for interesting changes. The blackboard type approach previously described can be implemented in MUSE using notice boards.

In the example of a MUSE application, depicted in Fig. 23a, three knowledge sources are utilised (KS1, KS2 and KS3). Each contain a central shared database (KS1-DB, KS2-DB, KS3-DB). These databases are visible to all the knowledge sources in the application and to Pop code. They can be specified in the "interests" of any production rule set which will then monitor any changes. In the example, each knowledge source has two rule sets (RS1/RS2, RS3/RS4, RS5/RS6). Each of these rule sets is either a FPS or BCS or any mixture. Each has its own private database (DB1/DB6) which is only visible to each individual rule set.

When the initial information of a problem is processed in the knowledge source KS1, the results are communicated in the plan notice board. The plan notice board can trigger the two knowledge sources KS2 and KS3 which have access both to the plan and the final output notice board.

The knowledge sources are schemas with in-built slots and methods. The "methods" which define the KS behaviour include "run" which produces the results of the knowledge source. Other methods are the "add" or "remove" which adds and removes objects from the shared database.

The order in which knowledge sources and other events are executed within the application is specified by the agenda. The agenda scheduling system is based on simple priority ordering. The agenda itself can be viewed as a fixed data structure with spaces representing different priorities. All the events which are ready to be executed are placed in the agenda by two methods. The first method is a function call from another part of the application. The second method is the "scavenger" which collects the production rule sets ready for execution. The agenda also allows reasoning chains to be suspended when new external events occur, thus, allowing alarm events to be processed immediately.

6. MARINE APPLICATIONS

Marine systems are basically ships or offshore platforms for drilling, construction and petroleum production. Expert systems for either the ship or the offshore platform sectors fall into two categories. First, the general advice type of expert system based on a dialogue mode (Fig. 24). Such systems can be designed initially to provide all members of the industry, ranging from shipbuilding experts to a ship's crew and classification society surveyors with the most updated information (rules, design standards, costs, etc) in suitably classified marine technology and management aspects. Interpretation of

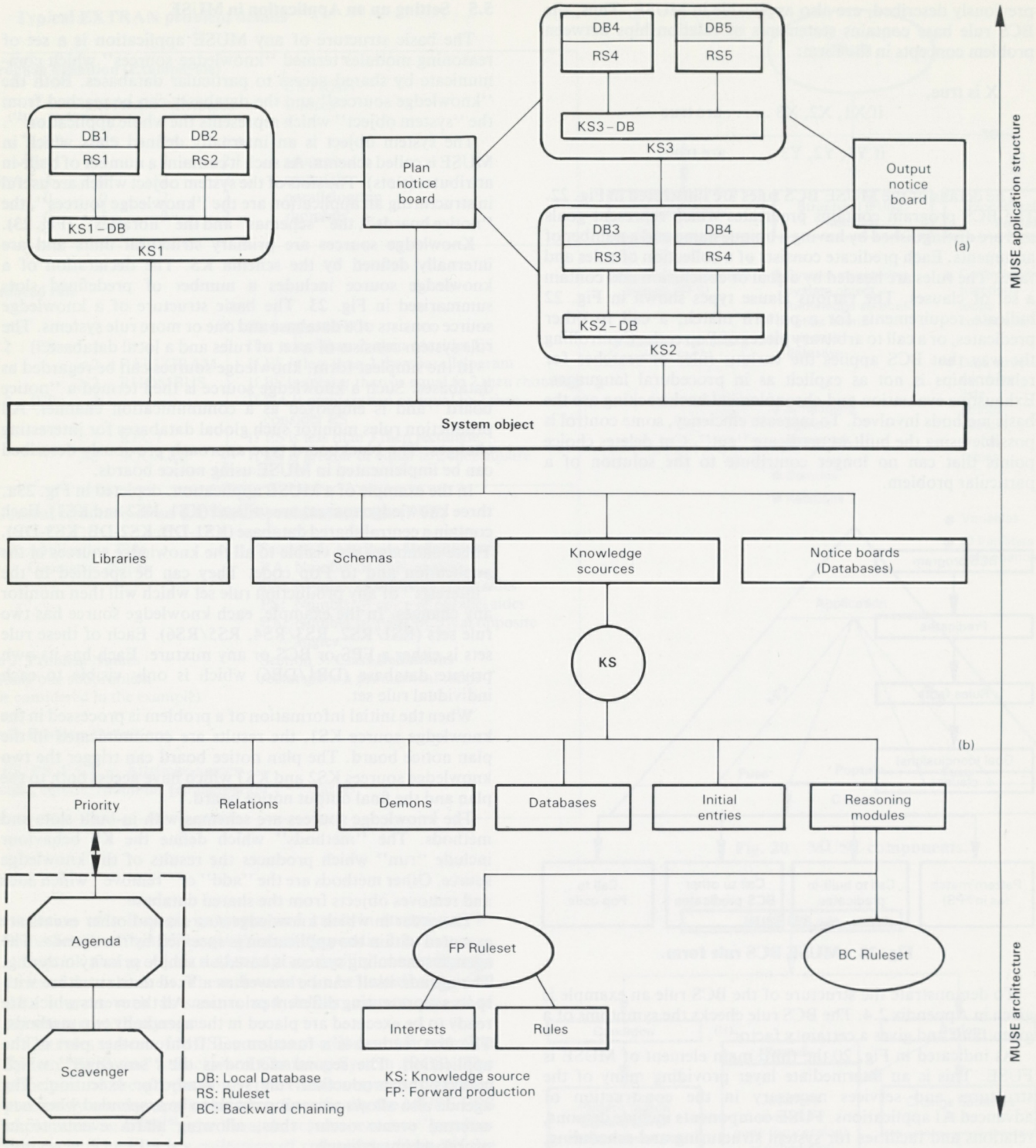


Fig. 23 Setting up an application in MUSE.

information and expert advice are the eventual goals of such systems[17, 18].

The second category is related to expert systems embedded in computer programs providing solutions to specific ship or platform functions. Such applications include voyage planning, engine fault diagnosis, and maintenance prediction in ships or platforms. A control expert system can produce the overall ship management function.

6.1 A General Marine Technology Expert System (MTES)

Marine transport technology can be broadly divided into two aspects, ship design and ship operation. Both are multi-disciplinary tasks influenced by factors which are external or internal to the ship. The two divisions can be integrated within the concept of a Marine Technology Expert System, (Fig. 25a).

External factors include environmental conditions such as winds and sea states, operational constraints such as voyage

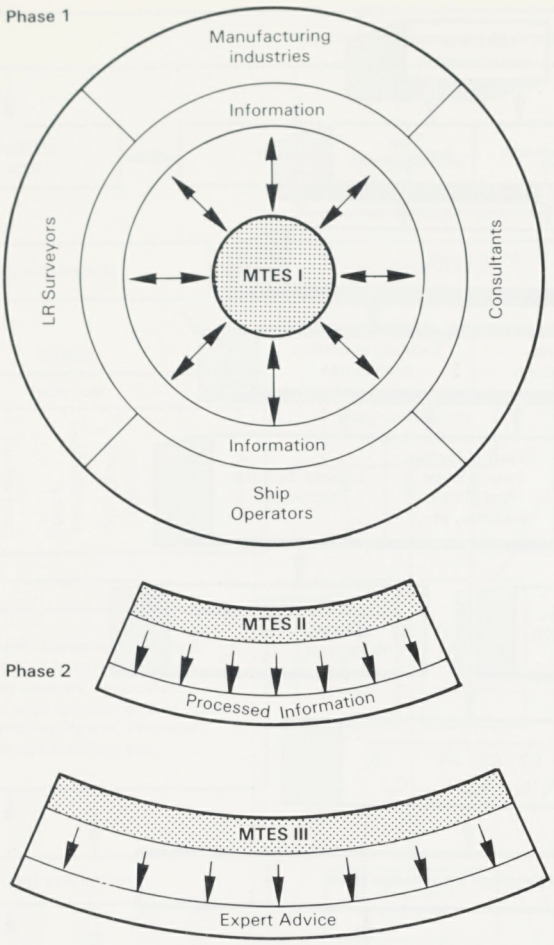


Fig. 24 Development of a marine Technology Expert System (MTES).

schedules or fuel quality, and broad economic and social issues. The environmental factors have been recognised and treated as probabilistic problems. Certain operational requirements can be considered within the appropriate cost equations, the majority are either neglected or judged intuitively. Furthermore, the critical economic factors such as the level of world trade, individual government policies, oil prices and freight markets are changing unpredictably making any attempt of mathematical modelling virtually impossible.

The internal factors are related to the areas of hydrodynamics, machinery, structures, stability, control, maintenance scheduling, management and many others. In all these areas mathematical modelling can be applied, although in many cases it can be argued, that the most serious obstacle is actually to define the problem. The necessary information for comprehensive mathematical modelling is often not available. Traditionally, preliminary solution parameters are derived and used sequentially as input for interconnected areas. The resulting initial design or operational parameters are then refined in an iteration loop. The widespread use of computer aided design (CAD) techniques makes an integrated synthesis approach suitable for this process. However, the difficulty arising from the variable interaction of internal design or operation factors according to criteria which are dependent on variable external factors cannot be resolved satisfactorily.

Utilisation of high technology in order to increase commercial competitiveness is considered to be the only viable course of action for many members of the marine industry. The realisation of substantial economic benefits from such a policy demands improvements in the well-known shortcomings of the existing technology. These shortcomings are invariably associated with technoeconomic scenarios and the interpretation of uncertain and unreliable information. This makes expert systems a promising access route to enhanced and consistent decision support for engineers and managers.

Ship design and management have been based on computer implementations of the traditional process of Analysis–Synthesis–Evaluation. These steps can be also accomplished by a Marine Technology Expert System (MTES) outlined in Fig. 25b. The analysis can be undertaken by a "ship information analysis expert system". The necessary input information will be made available from existing designs or operation procedures related to a suitable classification of goals. The knowledge representation can employ classes, objects and attributes as shown in Fig. 25b. The rules hence obtained, augmented by expert human knowledge (heuristics) will constitute a ship technology knowledge base. This will be operated by an inference system to establish specific goals and to perform the design synthesis. (A backward chaining rule system can be employed to search for parameters which satisfy the design goals; a production system can then perform the synthesis).

An advantage of this approach will be the adaptability of the system in formulating new solutions for changes associated with economic factors, different trading constraints, installation of new equipment and so on. Any change in the prevailing conditions will be accompanied by an automatic update of the problem description and consequent decisions. The effects of implementing each new decision can be subsequently monitored. Depending on the feedback information, the overall plan can be refined.

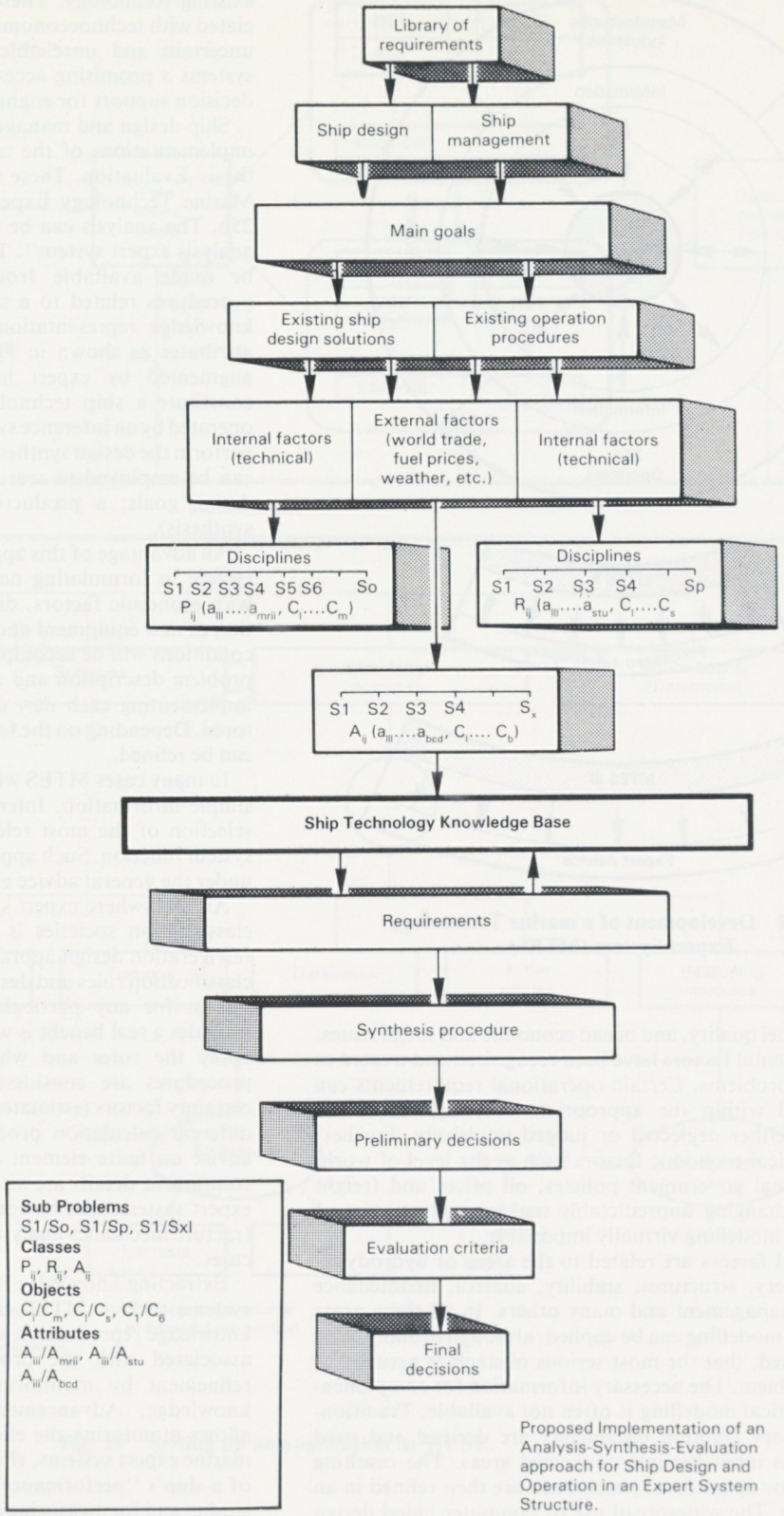
In many cases MTES will be only asked to provide relatively simple information. Interpretation of such requests and the selection of the most relevant information will be the main system function. Such applications have been already described under the general advice expert systems in section 3.5.

An area where expert system technology can be utilised by classification societies is in machinery, hull, electrical and refrigeration design appraisal and plan approval. The relevant classification rules and design standards can be identified by the system for any particular case. Where the expert system provides a real benefit is when it can provide advice on how to apply the rules and why certain formulae and appraisal procedures are considered to be applicable. Additionally certainty factors (estimates of safety factors) can be attached to different calculation procedures. Expert systems which will advise on finite element analysis in relation to loading and component details are already under development. Similarly, expert systems can be constructed to advise on what type of fracture mechanics analysis is the most appropriate for specific cases.

Extracting knowledge from humans and transferring it into systems such as MTES can greatly increase the efficiency of knowledge reproduction and exploitation. A further benefit is associated with the process of knowledge extension and refinement by monitoring the effect of applying existing knowledge. Advancements in communication technology allows monitoring the effects of advice given by shore based marine expert systems, (Fig. 25c). In particular, feedback data of a ship's "performance" is an essential input for reliability studies and for measuring goal attainment in the ship design and operational plan.

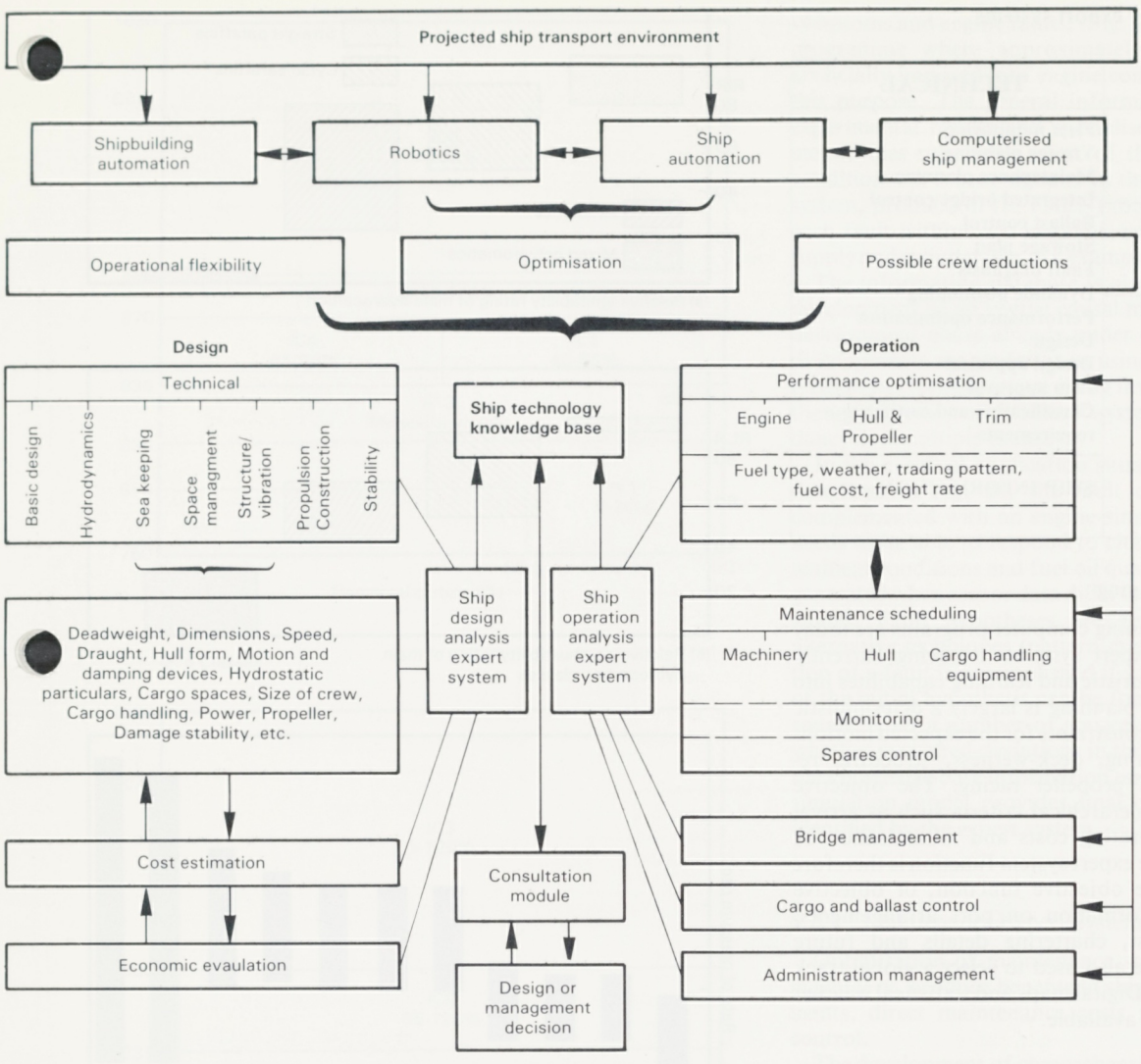
6.2 Specific Marine Technology Expert Systems

A number of expert system are being currently developed for specific marine applications, Table 6. Some of them are briefly described below, including two prototype expert systems under development by Lloyd's Register. The first is concerned with fuel characterisation according to measured fuel properties or engine performance measurements. The second is an expert system for engine fault diagnosis based on sensor readings.

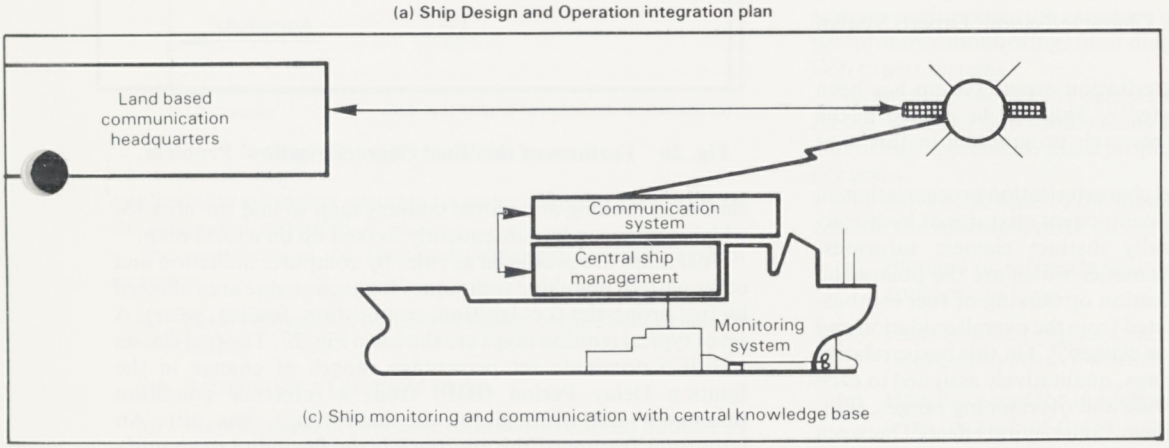


Proposed Implementation of an Analysis-Synthesis-Evaluation approach for Ship Design and Operation in an Expert System Structure.

Fig. 25 Development of an



(a) Ship Design and Operation integration plan



(c) Ship monitoring and communication with central knowledge base

integrated technology expert system.

Table 6 Marine technology export systems

FINANCIAL	TECHNICAL
Investment decision Business Plan Resource allocation	Fleet monitoring Voyage planning Maintenance planning Integrated bridge control Ballast control Stowage plan Fault diagnosis Dynamic positioning Performance optimisation Design Design appraisal Plan approval Classification and certification requirements
ADMINISTRATION	
Inventory control Inventory schedule Crew Accounts	
TRAINING	SHIP INFORMATION

6.2.1 Expert Voyage Planning

A number of voyage planning computer programs are today commercially available. Expert systems are being currently developed to encompass heuristic and learning capabilites into existing programs. Voyage planning is largely a deterministic optimisation problem with constraints for the expected motions (especially rolling), slamming, deck-wetness, structural response and the degree of propeller racing. The objective function is dependent on hierarchical criteria such as arrival time, minimisation of operating costs and minimisation of rough weather damage. The expert system function is therefore to identify the appropriate objective function, or objective function values, given information on port arrangements, bunkering ports, fuel cost, chartering details and future contracts. Heuristics can be also used to select a global track from knowledge base data. Digital maps and statistical weather forecasts are assumed to be available.

6.2.2 A Marine Fuel Oil Characterisation Expert System (FOCES)

A prototype fuel oil characterisation expert system has been developed by Lloyd's Register[17]. This will be refined in the course of an EEC funded research programme in this area currently under progress.

The initial point of any fuel characterisation process is that all fossil-derived fuels are multi-component mixtures of hydrocarbons from three structurally distinct classes: saturates, aromatics and mixed polyaromatics which are the polars and the asphaltenes. Any classification or ranking of fuel combustion behaviour can be elaborated from the overall oxidation and pyrolysis routes of these three classes[20]. On this basis, relative ignition and combustion ratings, qualitatively assigned to each hydrocarbon class, occupy wide and overlapping ranges, (Fig. 26a, 26b). In addition non-linear "interaction effects" between different hydrocarbons are present, producing a problem space of such complexity that traditional analytical treatment is virtually impossible. Apart from the chemical difficulties, the engine response variations create additional complications. The statistical distribution of combustion parameters such as ignition delay and rate of pressure rise portray large deviations from the mean values. The magnitude of this variance is fuel dependent, (Fig. 26c)[21, 22]. Under these circumstances the expert system approach has been selected for this application.

The fuel oil characterisation expert system is based on a two stage characterisation. The first stage is aimed at identifying a property area in a "fuel map" within which a second stage analytical procedure can establish a detailed correlation. This is

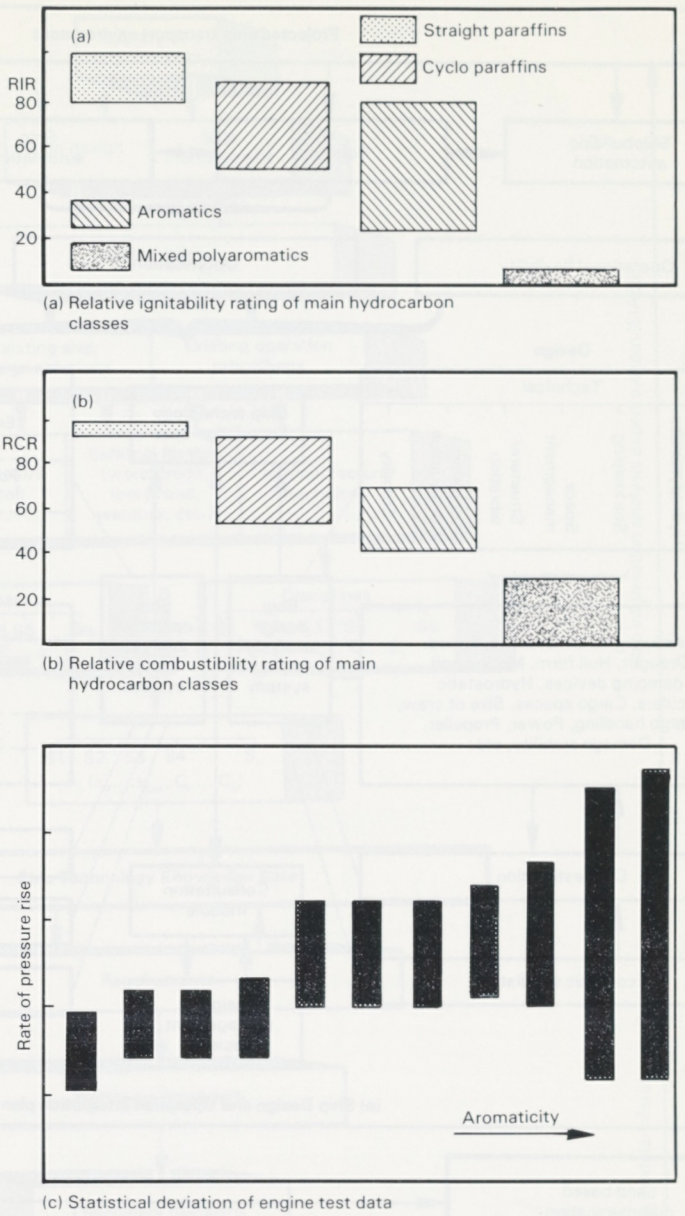


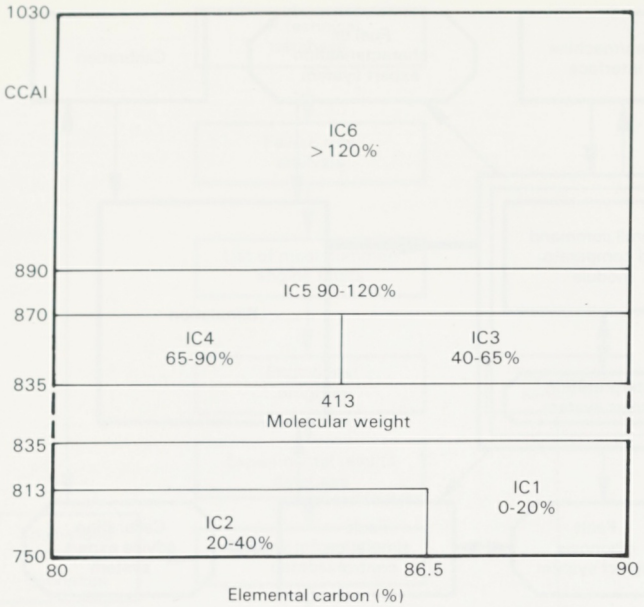
Fig. 26 Features of the 'Fuel Characterisation' Problem.

similar to looking at a global country map to find the area for which details can be subsequently looked up on a local map.

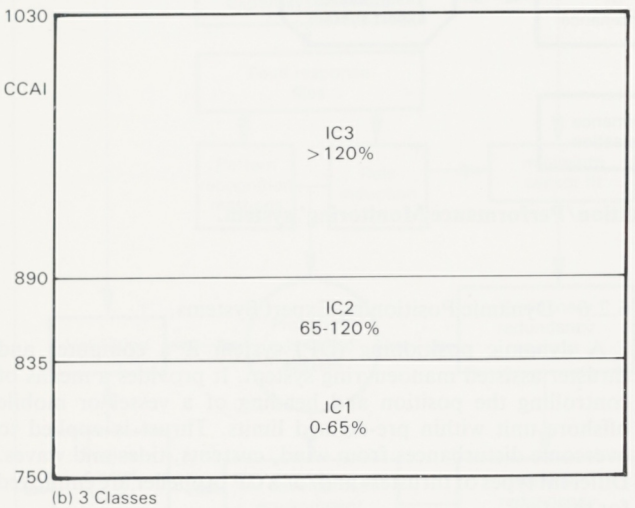
Fuel maps are produced as rules by computer induction and other pattern matching techniques for each engine area affected by fuel properties (i.e. ignition, combustion, fouling, wear). A set of typical ignition maps are shown in Fig. 27. The fuel classes IC1/IC6 nominate set percentage ranges of change in the Ignition Delay Period (IDP) from a reference condition (minimum IDP throughout the load range, gas oil). An important feature of the approach is the flexibility to simplify classification maps by broadening the ranges associated with the fuel classes. Only one fuel property is used in Fig. 27b.

6.2.3 Diesel Engine Fault Diagnostic Expert System

A fault diagnostic expert system is under development in the condition monitoring research programme coordinated by Lloyd's Register within the "UK efficient ship project"[23]. The fault diagnostic expert system together with the described FOCES will be integrated with a simulation module in a proposed advanced condition monitoring system. The conceptual system design depicted in Fig. 28 illustrates the wide



(a) 6 Classes



(b) 3 Classes

Fig. 27 IDP fuel class maps.

applicability of expert systems to assist different functions of the integrated system[24].

The specification of the fault diagnostic expert system includes:

(a) Early recognition of specific engine component or sensor faults.

(b) Recognition of multiple faults.

(c) Identification of probable faults with reduced number of sensors.

(d) Provision for reporting unrecognised changes in engine operating parameters.

(e) Advice to operator requesting additional information in the case of unrecognised conditions.

(f) Interface with other modules for the evaluation of future effects from the identified faults.

(g) Communication with the user allowing them to make a diagnosis and providing him with a critique.

The development of this expert system[24] is based on obtaining experimentally a database of associations between symptoms and engine faults, (Fig. 29). An extensive engine test programme where approximately 80 fault conditions are artificially imposed into engine components is undertaken for this purpose. The general information database consists of experimental results and specialised knowledge. The experimental files reflect the effect of the selected matrix of fault conditions on sensor signals. In the first prototype rule based system, production (If-THEN) rules have been generated for each fault within each engine subsystem such as air and fuel supply and cylinder line. An example is given in Appendix 3, (8).

The information database is also employed to assist in the development of an engine causal model during a second stage development phase already under progress. The second stage developments are undertaken using MUSE. Different pattern recognition techniques are being investigated, and in particular the applicability of "frame" systems to cover sensor redundancy and multiple faults.

In the eventual application situation, as part of the system described in Fig. 28, the fault diagnosis expert system is complemented with an engine simulation model. This model needs to be able to respond to changes in engine speed, load, ambient conditions and fuel oil quality. Deviation files are then generated when sensor data differ from the simulation reference values. Fault hypotheses are generated by a number of alternative techniques (pattern matching or rules). Confirmation of a fault is accomplished if sufficent supporting evidence of the initial hypothesis can be found. Supporting evidence is sought from a number of sources—one example is assessing whether measured deviations in the combustion pattern match the knowledge base information on the hypothesized fault. The simulation model provides final confirmation for any fault identified by the expert system.

6.2.4 Maintenance Expert System

Optimisation of maintenance schedules both for hull and machinery, produce benefits in ship availability, crew requirements, direct maintenance costs and spare parts inventory control.

The development of comprehensive ship maintenance expert systems presupposes the existence of sensors for condition and performance monitoring, fault diagnosis and fuel characterisation expert systems.

Maintenance activity is defined within physical subsystems. At the top level, ship subdivisions are the hull/propeller, cargo and lifting appliances, main propulsion and auxiliary machinery areas.

The knowledge base of the maintenance expert system must contain the following three sets of information:

(a) Planned or reference maintenance schedules for all the appropriate items.

(b) Factors which produce increased maintenance activity (fuel quality, heavy weather, etc.).

(c) Heuristics and/or models specifying deterioration patterns for each of the factors in (b).

Initial estimates of when maintenance is required will be entered in the commissioning stages of the equipment from the manufacturers planned maintenance schedules. These will be constantly updated by the reasoning modules for the system which will be triggered by "Demons" set to monitor factors responsible for increased maintenance activity (list b). Predictive maintenance can be formulated as a planning expert system. Heuristics can be employed to select appropriate parameters and/or models for estimates of change in maintenance schedules. It is envisaged that it will be necessary to monitor actual deterioration trends (for example, engine lubrication condition and accumulated debris) to refine the predicted maintenance plan.

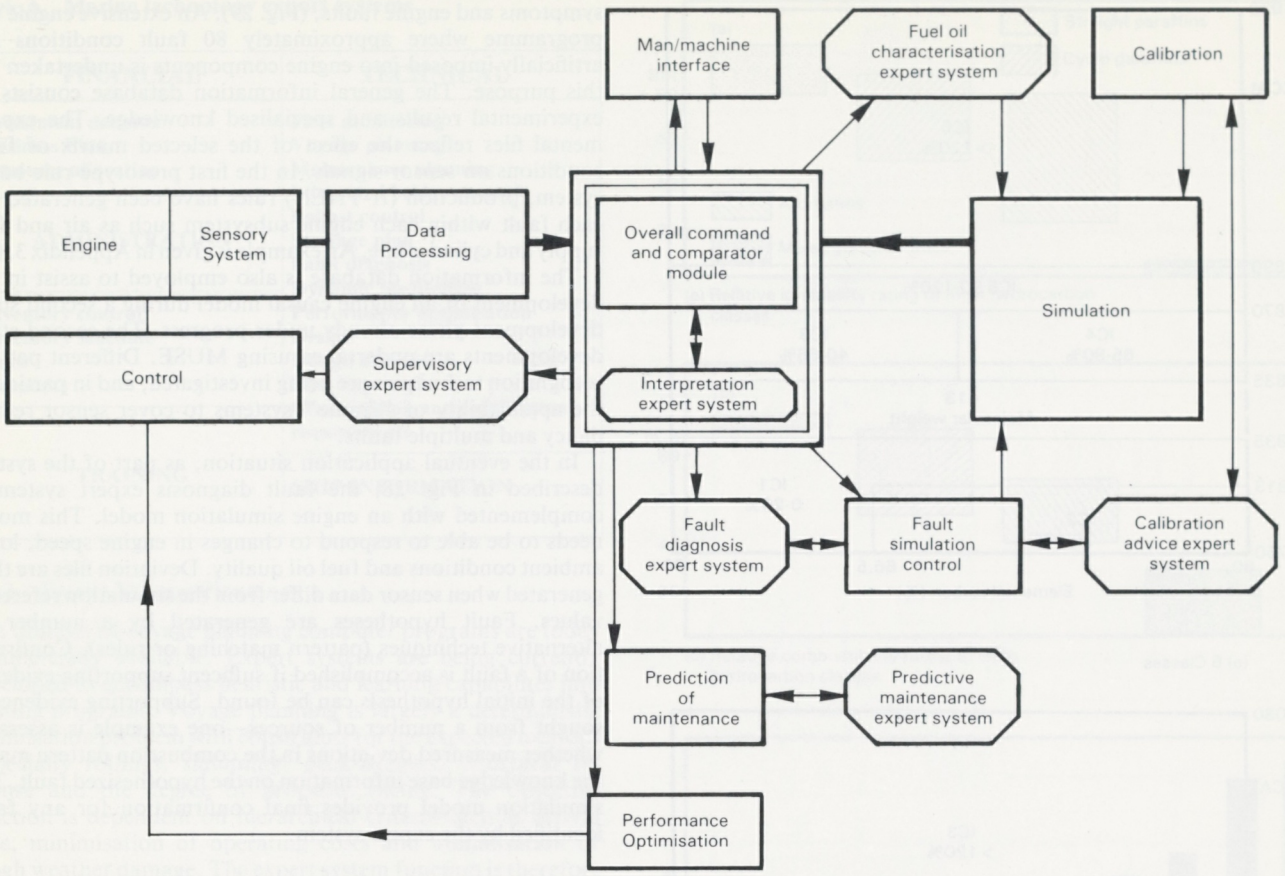


Fig. 28 Conceptual design of advanced 'Condition/Performance Monitoring' system.

6.2.5 Integrated Ship Control

Systems integration on ships refers usually to engine room control and cargo handling and sometimes communication, navigation and other systems. Total integration is however, the goal of many R & D activities and in particular the final aim of many national "efficient ship" projects.

Developments to integrate bridge control systems are on the way. The typical bridge operational system consists of the steering control, magnetic compass, and engine room telegraphs, radar, radio, gyro, echosounding and satellite signals. Electronic charts and a host of other instruments are also finding their way into the bridge area. Total integration of the bridge control, and further integration with the machinery control, cargo handling and surveillance systems into a central ship management area can impose overwhelming demands on both the computer hardware and, even more important, on the operators.

Because conditions can change rapidly during an emergency situation, a course of action that may at first be correct could moments later be disastrous. Assimilation and interpretation by the bridge officers of all the information available by all the described systems is virtually impossible. Furthermore no computer, regardless of its speed, can evaluate quickly enough all possible outcomes presented by an emergency. Expert system technology is almost an essential requirement in this area. Efficient inference mechanisms augmented by heuristics and effective knowledge representation techniques can offer a solution to the demands of this problem. A number of expert systems for intelligent process control have been already developed and marketed. Usually they act as alarm management systems by monitoring very large numbers of process variables and alarms. The knowledge base may contain a very large number of pre-programmed rules.

6.2.6 Dynamic Positioning Expert Systems.

A dynamic positioning (DP) system is a computer and thruster assisted manoeuvring system. It provides a means of controlling the position and heading of a vessel or mobile offshore unit within pre-defined limits. Thrust is applied to overcome disturbances from wind, currents, tides and waves. Different types of thrusters and/or a CP propeller are employed for this task.

Controllers for DP application are based on established multi-variable control theory. Normally, because ship motions have significant non-linearities, it is necessary to change control parameters (gain and phase) to obtain satisfactory control over the power range of a ship.

Expert systems have been developed in this area to act as AI supervisory controllers. Their role is to interpret prevailing conditions and to select a control mode with the appropriate controller parameters.

6.2.7 Offshore Platform Design

As an example of the application of expert systems in marine system design the offshore platform is chosen as representing the most complex design task. The design effort of a typical offshore development may take up to 10 million man-hours and involve hundreds of experts. The management demands, communication and monitoring aspects can benefit from the use of expert system technology.

The overall objective in developing a field is to exploit a petroleum reservoir in the most economical manner. Suggested development concepts consistent with a production plan are reviewed and refined in the light of environmental, technical, and economic constraints. These constraints include weight, cost and time estimates, phasing of activites and field

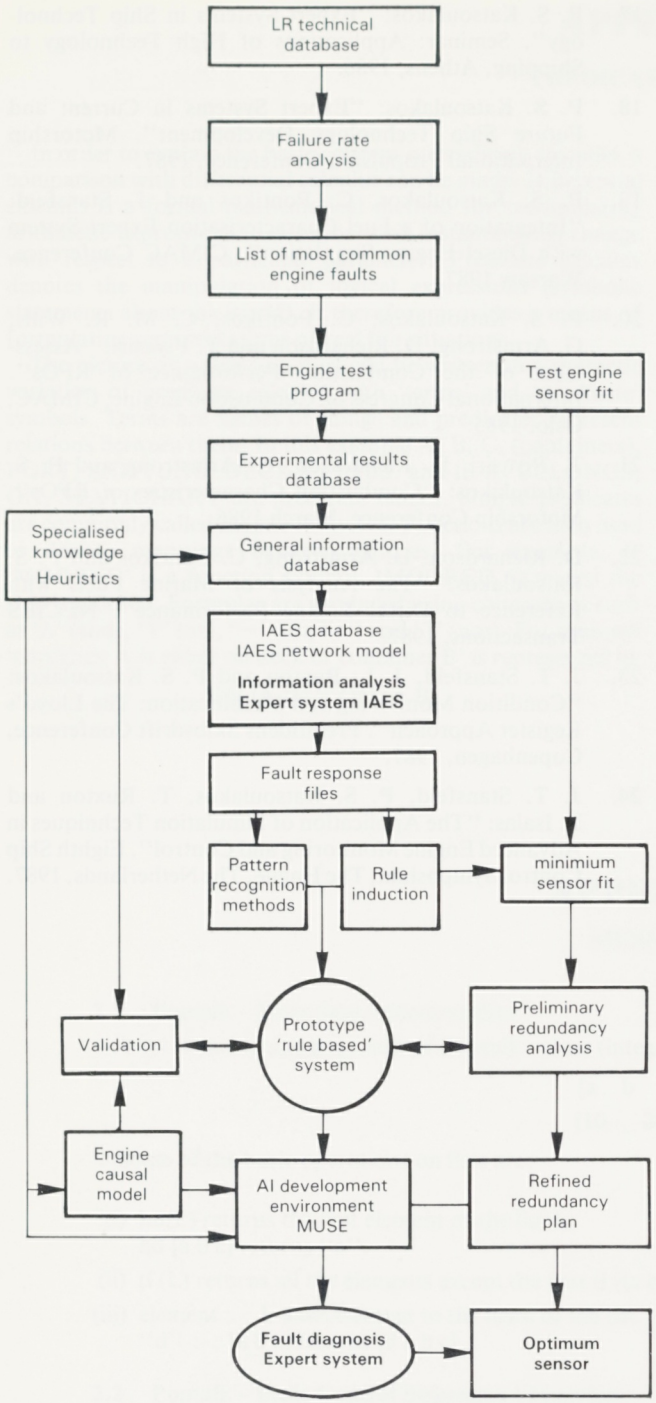


Fig. 29 Development of a fault diagnosis expert system

development economy. The planning and monitoring expert systems are particularly suited for this application.

Expert systems to assist in offshore platform design are being developed in a number of research projects. A frame system consisting of a collection of related frames can be employed to suggest known concepts which are relevant to a given specification. The attributes of objects within each frame can be clearly identified. When all necessary frames have been adapted to reflect as closely as possible the design goals, advice on design parameters can be given.

7. CONCLUSIONS

The industrial revolution has been succeeded by the information technology era—a mixture of computers and communications encompassing knowledge based systems. Information technology is giving the marine industry the opportunity to change once again. This can be accomplished by raising the technological level of ship transport to enable the generation of new products and services in a technically competitive environment. The determinant of success will depend on the ability to develop and rapidly exploit the new technology. The use of this technology in a coherent and disciplined way requires comprehensive knowledge of its advantages and limitations. Such knowledge is also necessary for the independent assessment of its impact on safety and ship integrity.

Future developments towards Integrated Ship Management systems will rely on developing new techniques for diagnostic, predictive, planning and control functions and for interpreting information which is unclear, uncertain and unreliable. Expert systems are particularly suitable to these problems and could inevitably become an essential element in marine technology. This would be further supported by the accessibility of the expert system's knowledge base when parameters change due to the inherent dynamism of the ship transport and offshore platform environment. The "knowledge base", can be changed easily as operating experience with a ship or a platform is gained; or as machinery, equipment, trading patterns, or economic factors are modified. This can be further facilitated by the use of the Information Analysis Expert System to translate automatically new information into a format for direct implementation into a rule generation procedure.

The analysis-synthesis-evaluation approach, used traditionally for ship design and to a certain degree ship management can be implemented using an expert system. In the proposed conceptual framework for such applications the analysis process to establish ship design or operating parameters can be undertaken by an information analysis expert system. Knowledge structures from exisitng ship design or operation details can be then related to specific goals. In certain cases heuristic rules and links to external deterministic models will be added to complete the ship technology knowledge base. The knowledge base can be operated through an inference system to produce solutions or advice for new design or operation objectives.

8. ACKNOWLEDGEMENTS

The author would like to thank the Department of Trade and Industry, the Science Engineering Research Council, the Council of the European Communities and many industrial and research participants for their support in the Society's research programme. The author would like to thank Dr. D. Reynolds and Mr. I. Dickinson of Cambridge Consultants Limited for their help and advice and also Dr. J. Newland who is responsible for the software development of expert systems in the AES research programme and his colleagues who are contributing to the work.

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APPENDIX 1

PREDICATE CALCULUS

In order to explain the basic concept of predicate calculus, a comparison with differential calculus can be made. Differential calculus is a formal mathematical method for manipulating arithmetic expressions to describe their instantaneous change with respect to a particular parameter. Predicate calculus denotes the manipulation of logical expressions (symbolic statements about the world). It therefore provides a means of formulating representations of real life situations.

The picture of a ship in a port can be written in a syntactic variation of predicate calculus with 'terms' and 'predicate' symbols. Terms are names of things and predicates represent relations between them. In this example A, B, C, (containers), PORT, SHIP, SHIP DECK are terms, and IS-A, BELONGS, ON, STATIONARY are predicate names. Simple predicates are commonly called atomic formulae. Functions are then used to denote mappings between entities. For example, if 'MOORED' is a function symbol, (MOORED S) means the ship is moored. Formulas are produced using connectives such as 'Λ' (and), 'V' (or), '→' (implies) and '¬' (not). For example 'container A is either on deck or container B' is represented by

ON (A D) V ON (A B)

Predicate calculus can also express sentences involving quantifiers like 'All containers are standard size'. This would be expressed as

(∀x) [CONTAINER (X) → STANDARD (X)]

Apart from the universal quantifier '∀', the existential quantifier '∃' is equally important. It indicates that the formula is only true at certain times when for example a variable is assigned a specific value.

Formulas based on terms, atomic formulaes, connectives and quantifiers are called 'well-formed formulas' (Wffs). Predicate calculus provides a number of well defined rules for combining formulas. Reasoning is accomplished by producing new formulas (Wffs) by applying inference rules to sets of existing ones. For example, we might have the following inference rule for predicate MOORED

(ALL (X) (ALL (Y)) (((IN X Y) Λ (STATIONARY X))→
(MOORED X Y))))

If ship X is in port Y and is stationary it is moored in port.

APPENDIX 2

MUSE Details

2.1 Poptalk - Basic data structure: lists

A list is an ordered sequence of Poptalk values (integers, reals, words, objects). An example is given below

[a b c a d]
[10 20 30.5]

Some of the basic operations on lists are:

(i) hd(L) returns the first element of the list L,
hd [a b c] returns "a".

(ii) tl (L) returns all the elements except the first tl ([a b c]) returns [b c].

(iii) element : : L adds element to the head of the list.
"d" : : [a b c] returns [d a b c]

2.2 Poptalk - Basic Control Structures : Functions

A functions is declared by:

function function name (input paramaters) output parameters local variables
end function

Example: Consider a function to compute the percentage change of a measured parameter (Y) from its reference value (X):

```
function  percent (x, y) → result;
                (y-x) * (100/x) → result;
end function;
```

which is called by:

```
percent (10, 15) r
```

and will return r = 50.

2.3 FPS rule example

To illustrate the structure of the FPS rules an example is given below. The rule is formulated to detect a match between a hypothesis of a fault and an observed change in a sensor value.

if

there is a fault F, – name F_n

and

there is a hypothesis H, – support F_n

and

there is a sensor S,
– changed true
– sensor fault no
– name S1 where
(member (S1, F:symptoms))

Schema : sensor	*Instance of schema : sensor ; S*	
Slots :	*Slot values for S :*	
changed	*true*	*Sensor S1 which*
sensor fault	*no*	*is functioning properly*
name	*S1*	*has changed from a reference value*

Poptalk test to check that sensor S1 is a member of the list of symptoms attached to fault F. (Member) is a built-in function in Poptalk.

and

do (S1 : : H : evidence → New evidence)

then

assert (hypothesis H: evidence → New evidence)

Notation

Slots (Attributes)	– name – support – changed – sensor fault	Schemas (Classes)	– fault – hypothesis – sensor – evidence

F, F_n, H, S, S1 New Evidence: Variables
symptons: List

2.4 BCS Rule Example

This BCS rule takes the name of a hypothetical fault that has been detected, and returns a grade of the match between that fault and the current sensor values. The grade is one of:

"very_weak", "weak" or "strong".

	rule checkfault (Fault, Grade) **provided**
pattern match	there is a fault in KS1 – name Fault **and**
PopTalk code	do (Fault: symptoms → Symptoms) **and**
call another BCS predicate	check_symptoms (Symptoms, Fault, strong, Grade)
finished recursing	**fact** check_symptoms (nil, Fault, Grade, Grade)
split the list up	**rule** check_symptoms (SList, Fname, State, Grade) **provided** do (SList.hd → Symptom; SList.t1 → Remaining) **and**
pattern match	there is a sensor in KS1 – name Symptom, – value Svalue **and**
call another BCS predicate	map_state (Fname, Svalue, State, NewState) **and**
recurse	check_symptoms (Remaining, Fname, NewState, Grade)

map_state is a BCS predicate that maps the current state, and the comparison between the expected and actual values, into a new state.

APPENDIX 3

Rule generation using EXTRAN

The mechanism for generating rules is clearly illustrated by considering the FUEL engine subsystem. With reference to Table 3.1.1 seven solution parameters (classes) are used in the definition of this sub-problem.

The first six, (I01, I02, I03, I04, I05, I06) are indications of specific component faults which can occur in the fuel subsystem.

The seventh (ISFFUE), is an indication of a sensor fault in the fuel supply sensory system. The general class of ISFFUE for sensor fault is used in this example for simplicity. The subproblem attributes are the engine parameters which change as a result of all the possible faults within the FUEL subsystem, in this case I01 . . . I06. In Tables 3.1.1 the names of these attributes are sensor signals FSS1, FSS2 . . . FSF2. The value of each of the attributes is the magnitude of the relative change in accordance with the classification scheme where 1 means no change, and 7 maximum change.

The rule induced from the FUEL subproblem is given in Table 3.1.2.

TABLE 3.1: Results from Fuel 'Indication' analysis.

3.1.1 Example File

	Attribute									Class
	FSS1	FSS2	FST3	FST5	FSP1	FSP2	FSP3	FSF1	FSF2	
1	1	2	1	4	1	5	7	1	3	I01
2	1	3	4	5	2	3	4	7	4	I02
3	1	1	6	5	3	6	7	7	5	I03
4	1	3	1	4	3	3	7	1	4	I04
5	3	3	5	1	1	1	7	7	6	I05
6	4	3	2	5	4	6	6	1	7	I06
7	3	1	1	1	1	1	1	1	1	ISFFUE
8	1	3	1	1	1	1	1	1	1	ISFFUE
9	1	1	4	1	1	1	1	1	1	ISFFUE
10	1	1	1	4	1	1	1	1	1	ISSFUE
11	1	1	1	1	3	1	1	1	1	ISSFUE
12	1	1	1	1	1	3	1	1	1	ISSFUE
13	1	1	1	1	1	1	4	1	1	ISSFUE
14	1	1	1	1	1	1	1	7	1	ISFFUE
15	1	1	1	1	1	1	1	1	3	ISFFUE

3.1.2 Rule File

```
{FSP3} :                                  First consider FSP3
   1-4  : {FST5} :                        If FSP3 is 1-4, consider FST5
             1-4  :  ISFFUE               If FST5 is 1-4 , then ISFFUE
             5-7  :  I02                  If FST5 is 5-7, then I02
   5-7  : {FSS1} :                        If FSP3 is 5-7, consider FSS1
             1    : {FSS2} :              If FSS1 is 1, consider FSS2
                       1   : I03          If FSS2 is 1, then I03
                       2   : I01          If FSS2 is 2, then I01
                      3-7  : I04          If FSS2 is 3-7, then I04
             2-3  : I05                   If FSS1 is 2-3, then I05
             4-7  : I06                   If FSS1 is 4-7, then I06
```

LLOYD'S REGISTER TECHNICAL ASSOCIATION

MINUTES OF THE 1987 ANNUAL GENERAL MEETING

The Annual General Meeting of the Technical Association was held in the Committee Luncheon Room on Wednesday, 29th April, at 1600 hours. Thirty four members attended.

The President of the Association, Mr. L. Beckwith, occupied the chair:

AGENDA

1. Apologies for absence.
2. Approve and sign minutes of the last AGM.
3. Matters arising from the last AGM.
4. President's Review.
5. Hon. Secretary's Report.
6. Assistant Hon. Secretary for Corresponding Members' Report.
7. Hon. Treasurer's Report.
8. Proposed Syllabus for 1987/88 Session.
9. Election of Committee for the 1987/88 Session.
10. Newly elected Committee to assume office.
11. Any other business.

Each item on the Agenda was dealt with as follows:

ITEM 1

There were no apologies for absence.

ITEM 2

The Minutes of the last AGM, held on the 28th May, 1986, were examined by the members present. The minutes were unanimously approved without amendment and signed by the Chairman.

ITEM 3

There were no matters arising from the last AGM.

ITEM 4

In his review of the past year the President, Mr. L. Beckwith, said:

"At the halfway stage in my period as President I am pleased to report that the Association has successfully been able to continue its work in the promotion of technical information and guidance to its members.

The technical quality of the papers and the standard of presentation are very high, as will be confirmed by those members who have also attended at commercially organised Seminars and Conferences where this is not always the case. I would thank all the authors who devoted their time and energy in the preparation of the papers for this last Session. It is pleasing to note that three of the papers have been selected by Lloyd's Register for wider circulation as Technical Reprints, thus confirming their high standard.

It is regrettable that the topics of some papers do not attract the attention of many members and consequently attendance at the presentation is less than one would desire. The Committee will be giving renewed attention to this matter during the forthcoming Session, particularly with respect to invitations to selected guests which has proved to be so well received at outport meetings in the past.

Lloyd's Register is going through a period of change and this will be reflected in the organisation of the Technical Association's affairs where necessary. A review of the representation on the Committee is presently being carried out and in the election of Committee Members later you will note that one additional representative for Safety Technology and Computer Services has already been agreed.

The Corresponding Members of the Committee often receive little recognition of their work and I would take this opportunity to thank them for promoting the interests of the Technical Association in all parts of the world. I would also ask that they renew their efforts to obtain written contributions to the papers presented in London and encourage prospective authors to make themselves known, after all you represent the majority of the membership.

Finally, I would thank those Officers and Committee Members who are retiring at this meeting for all their hard work."

ITEM 5

The President called upon the Hon. Secretary to report on the Association's activities during the Session. Mr. Magill advised the meeting as follows:-

"The Technical Association has had a very active year during which six technical papers were presented and a Guest Lecture is to be given at the conclusion of this meeting.

On looking back at the Reports given by myself and other Secretaries in previous years it has been noted that the proposed programme of technical papers has often been different to the programme as presented and this year is no exception, there being two changes to the syllabus given at the last AGM. The papers presented were:-

Paper	Author	Title	Attendance
1	B. W. Oxford	Inert Gas and Venting Systems	104
2	R. W. Jakeman	Sterntube Bearings : Performance Characteristics and Influence on Shafting Behaviour	48
3	C. M. Magill	Control of Pollution by Noxious Liquid Substances in Bulk	44
4	D. M. Richards	Heated Submarine Pipelines	41
5	W. J. Winkworth	Strength Analysis of Self-Elevating Units	49
6	M. Kmiecik (Guest)	A Review of Fabrication Tolerances in Light of the Compressive Strength of Plates	37

As will be noted, the attendance at meetings during the last year has fallen back to a level similar to that of a few years ago. It is not known if the large number of retirements in late 1986 has directly been responsible but certainly some familiar faces who gave regular support are no longer with us. I would encourage the Committee Members to actively promote larger attendance during the forthcoming year.

The Printing House at Crawley was privatised during the last Session and a re-appraisal of the Technical Associations method of working with Lloyd's Register Printing Services Ltd. was necessary. An internal budget for the cost of the printing and distribution of technical papers is now agreed with Lloyd's Register at the commencement of each Session. In order to fulfil one of the conditions of the budget allocation, new "Instructions to Authors" and "Guidance for Referees" have been developed to ensure the suitability of papers for publication. A review of Staff members and locations has also been carried out in order to reduce the overall cost of the Technical Association's activities.

This marks the end of my period of Office as Secretary and I would like to thank my colleagues on the Committee for their assistance in the various activities during this time, teamwork is so essential to the smooth running and strength of the Technical Association. A special mention is also due to Don Rennie and Les Beckwith as Presidents and Don McKinlay as Vice-President who have all given me so much help and support during some difficult times. It has been greatly appreciated."

The Chairman then acknowledged the work of the Secretary, drawing attention to the amount of work carried out in addition to normal LR activities and how much of this additional workload is dealt with outside office hours.

ITEM 6

The Chairman asked the Assistant Hon. Secretary for Corresponding Members to give his report. Mr. Frize advised the meeting as follows:-

"The LRTA Medal for the 1985-86 Session was awarded to Messrs. A. D. Cameron and R. V. Pomeroy for their paper "Engineering Fracture Mechanics : An Introduction and Review."

The only LRTA paper to be read outside Headquarters last year was "Strength and Fatigue Analysis : the North Sea Experience" by C. A. Bainbridge on 3rd March 1987 to the Glasgow branch of I. Mar. E., LR being the sponsor of the meeting (not solely LRTA).

Changes of Corresponding Members are as follows:-

1. Mr. F. B. Last, Sydney retired. Nominee Mr. A. M. Shepherd.
2. Mr. D. Terno, Dusseldorf transferred. Nominee Mr. K. D. P. Nusken.
3. Mr. A. Schreuder, Rotterdam retired. Nominee Mr. B. P. T. Wegenhousen.
4. Mr. H. Milne, Hull retired. Nominee Mr. P. J. Beaman, Middlesbrough.
5. Mr. W. F. Rogerson, Aberdeen retired. Nominee Mr. G. Lambton.
6. Mr. D. G. Gaskell, Liverpool transferred. Nominee Mr. A. D. Muncer.

I wish to thank all Corresponding Members for their contributions to the success of the Medal Awards Scheme but also wish to encourage Members to play a more active part in the affairs of the Association. In particular, suggestions of subjects for possible future papers would be welcomed as would more written contributions to the papers."

ITEM 7

The President then asked the Hon. Treasurer to present the statement of the Association's finances during the past year. Mr. Sharman presented the financial statements reproduced at the end of the AGM Minutes.

No comment was made by the members present.

ITEM 8

The Chairman asked Mr. McKinlay, the Association's Vice-President and Chairman of the Sub-Committee on Technical Papers, to present the proposed syllabus for the 1987/88 Session. Mr. McKinlay advised the meeting as follows:-

"The Sub-Committee on Technical Papers met four times during the 1986/87 Session to develop the programme of meetings and papers for the forthcoming sessions. There has been a healthy response from members of the technical staff which means that a well-balanced programme can be offered for the next session and, in outline, for the 1988/89 Session.

The proposed programme for the 1987/88 Session comprises seven papers for presentation at evening meetings, two papers for written discussion and a guest lecture as follows:-

Paper No. 1 An Introduction to Artificial Intelligence and a Review of Engineering Applications by P. S. Katsoulakos of AES

Paper No. 2 Electric Propulsion by B. P. Sharman of Electrical and Control Engineering Dept.

Paper No. 3 Survey of Safety Equipment by C. H. A. Marshall and J. V. Rugg of ICD.

Paper No. 4 Inspection of Nuclear Installations by G. S. Scoones and R. Porter of LRIS.

Paper No. 5 Electronic Mail and Communications by C. J. J. Beart of Computer Dept.

Paper No. 6 Automated Inspection Equipment by J. Speake of RTD Panatron.

Paper No. 7 40 years of International Conventions by L. Beckwith of ICD.

Paper No. D1 Hull Attachments by M. Komori formerly of Hiroshima.

Paper No. D2 A Negative Binominal Model for Reliability Assessment by D. A. Triner of TRO.

The Guest Lecture will be given by the Director General of the General Council of British Shipping, Mr. P. Le Cheminant.

The outline programme for the 1988/89 Session which is under consideration includes papers on the following subjects:-

Propeller Hydrodynamics
Type Approval
Flame Spraying
Stability
Steering Gear
Lifting Appliances

The Sub-Committee believes that this constitutes a full and varied programme but expresses a concern, voiced at several previous AGMs, that there continues to be a shortage of offers of papers relating to hull design and construction."

There was no comment from the members present and the proposed syllabus for 1987/88 Session was adopted.

ITEM 9

The President requested the Hon. Secretary to advise the AGM on the election of Officers to the Committee.

Mr. Magill read out the list of names nominated for the Officers, Members of Committee and Corresponding Members of Committee. Except for the position of Committee Member representing TID/AES, there was only one nomination for each office and the nominees were duly elected. The members present then cast their votes for each of the nominees wishing to represent TID/AES and the Secretary declared that Mr. N. A. Hall-Stride had been elected. The names of all those elected are recorded below.

President	Mr. L. Beckwith
Vice-President	Mr. D. McKinlay
Hon. Secretary	Mr. R. V. Pomeroy
Asst. Hon. Secretary	Mr. A. G. Gavin
Asst. Hon. Secretary for Corresponding Members	Mr. J. Frize
Hon. Treasurer	Mr. B. P. Sharman

COMMITTEE MEMBERS:

Classification Reports	Mr. D. B. Parkin, Mr. A. B. Merchant
Hull New Construction	Mr. P. Stringer, Mr. A. J. Williams
Industrial Services	Mr. E. D. Stephenson
International Conventions	Mr. F. R. Hales
MDAPAD	Mr. R. Jeffrey
Offshore Services	Mr. D. Harris
Refrigeration	Mr. J. Rushmer
Research Laboratory	Dr. F. A. Khayyat
TID/AES	Mr. N. A. Hall-Stride
Safety Technology/Computer Services	Mr. S. R. Collins

CORRESPONDING MEMBERS OF THE COMMITTEE:

AUSTRALASIA	Mr. A. M. Shepherd	SYDNEY
BELGIUM AND FRANCE	Ir. W. J. G. de Backer	ANTWERP
CANADA	Mr. C. A. C. MacGregor	MONTREAL
CENTRAL AMERICA AND THE CARIBBEAN	Mr. F. Klug	MEXICO CITY
CENTRAL EUROPE	Mr. C. M. Bergmann	HAMBURG
	Mr. D. Nusken	DUSSELDORF
CENTRAL ORIENT	Mr. J. N. Mckay	BUSAN
EASTERN MEDITERRANEAN	Mr. J. J. Stansfield	PIRÆUS
IBERIAN PENINSULA	Mr. H. Garcia	MADRID
INDIA AND PAKISTAN	Mr. S. V. Ramchandani	BOMBAY
ITALY AND MALTA	Dott. Ing. G. Perrotta	GENOA
JAPAN	Mr. A. Kamitami	OSAKA
	Mr. R. Hashiguchi	SHIMONOSEKI
	Mr. K. Seki	YOKOHAMA
MIDDLE EAST AREA	Mr. S. M. Miskry	BAHRAIN
NETHERLANDS	Mr. B. P. T. Wegenhousen	ROTTERDAM
NORDIC COUNTRIES	Mr. J. G. Lassen	COPENHAGEN
	Mr. R. S. Malmberg	GOTHENBURG
NORTH AFRICA	Mr. S. M. A. Ahmed	ALEXANDRIA
POLAND	Mr. A. Barrett	GDANSK
SOUTH AMERICA	Mr. R. De. F. Gomes	RIO DE JANEIRO
SOUTHERN AFRICA	Mr. C. A. Timms	DURBAN
SOUTHERN ORIENT	Mr. B. H. Wong	SINGAPORE
UNITED KINGDOM:		
EAST MIDLANDS	Mr. P. J. Beaman	MIDDLESBROUGH
NORTH ENGLAND	Mr. A. J. O'Connell	NEWCASTLE
NORTH SCOTLAND	Mr. G. Lambton	ABERDEEN
SOUTH EAST	Mr. C. D. Wilkie	LONDON
SOUTH SCOTLAND	Mr. J. F. Cooper	GLASGOW
SOUTH WEST AND SOUTH WALES	Mr. D. G. Taylor	SOUTHAMPTON
WEST MIDLANDS AND EIRE	Mr. A. D. Muncer	LIVERPOOL
UNITED STATES OF AMERICA	Mr. W. E. Tuck	NEW YORK

The Hon. Secretary also advised the meeting that the Honorary Auditors, Messrs. Leighton and Mounch, were willing to act in this capacity for the 1986–87 Session. The meeting then re-elected Messrs. Leighton and Mounch to continue in office for a further year.

ITEM 10

At this point in the meeting the retiring officers stepped down and the new members of committee took up their office.

Mr. Beckwith, President, introduced the new Session by expressing Association's thanks to those Committee Members who had retired and gave a welcome to those who had taken up office.

ITEM 11

There being no further business the President closed the meeting at 16.35 hours.

L. Beckwith
President

R. V. Pomeroy
Hon. Secretary

LLOYD'S REGISTER TECHNICAL ASSOCIATION

Income and Expenditure Account for year ended 31 March, 1987

	£	£
Sale of 115 binders		252.00
Less:		
Cost of binders Sold	251.85	
Surplus		0.15
Less:		
Expenditure		
Gratuities	66.80	
Entertainment	90.00	
Engraving	40.00	
		196.80
Excess of Expenditure over Income		(196.65)
Grant from Society		300.00
Net Surplus		**£103.35**

Cash Budget for 1987-88 is as follows:

		£
Balance of cash 1.4.87		454
Less:	Cost of entertaining, gratuities plus margin for contingencies	250
	Estimated surplus	**204**

Note: 1. It is assumed that cost of postage will continue to be borne by the Society.

2. The volume of binder sales is unpredictable, therefore, no account of this has been taken in the above figures.

3. No account has been taken of the repayment due to the Society in respect of the balance of loan remaining of £1,100.

D. Leighton, F.C.C.A.
M. Mounch, F.C.C.A. } Joint Auditors

24th April, 1987

LLOYD'S REGISTER TECHNICAL ASSOCIATION

Balance sheet as at 31st March, 1987

1986			1987	1986		1987
£			£	£		£
	General Fund					
507.52	Balance B/F	701.85		431.58	Cash at Bank (Current A/C)	454.18
				15.00	Cash in Hand	–
194.33	Plus Net Surplus/(Deficit)	103.35	805.20	1,065.27	Stock of ring binders in hand at cost	1,353.42
701.85						
1,350.00	Loan from Lloyd's Register		1,100.00			
2,051.85			1,905.20	2,051.85		1,905.20

N.B. Stock has been valued at lower of cost or net realisable value.

Report of the Auditors to the Members

The above Balance Sheet and attached Income and Expenditure Account has been drawn up from the documents and vouchers of the Association and the explanations given by the Officers thereof. We have examined the Income and Expenditure Account and the Balance Sheet and are satisfied that they show a true and fair view of the activities of the Association for the year ended 31st March, 1987.

D. Leighton, F.C.C.A.
M. Mounch, F.C.C.A.
} Joint Auditors

24th April, 1987.

L.R.T.A. RING BINDER ORDER FORM

L.R.T.A. Ring Binders may be obtained from the Hon. Treasurer at £2.20 each.
To place an order complete this page and send it, together with your remittance to:

B. P. Sharman,
Hon. Treasurer, L.R.T.A.,
Electrical Engineering Department,
71 Fenchurch Street,
London, EC3M 4BS.

Please send me.....L.R.T.A. Ring Binder(s).

I enclose £.....payable to Lloyd's Register Technical Association, preferably drawn on a British bank.

Name:

Dept./Outport:

Signed:

Date:

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Discussion

on the paper

AN INTRODUCTION TO ARTIFICIAL INTELLIGENCE AND MARINE SYSTEMS APPLICATIONS

by

P. S. Katsoulakos

Paper No. 1. Session 1987–88

FOR PRIVATE CIRCULATION AMONGST THE STAFF ONLY

Any opinions expressed and statements made in this Discussion Paper are those of the individuals.

Hon. Sec. A. G. Gavin
71 Fenchurch Street, London, EC3M 4BS

Discussion on the Paper

AN INTRODUCTION TO ARTIFICIAL INTELLIGENCE AND MARINE SYSTEMS APPLICTIONS

by

P. S. Katsoulakos

DISCUSSION

From Mr. R. V. Pomeroy:

It is somewhat unusual for the Secretary of the Association to open the discussion at an evening meeting but I have elected to do so on two counts. Firstly I wish to express my thanks to the author for preparing a very useful paper on a highly technical subject which is looking rather further ahead than is the norm with LRTA papers. The paper was written in very quick time in order to fill a gap in the programme. In fact the paper was only commenced at the time the final text was required but this enthusiastic response by the author has been reflected in the content of the paper and the presentation.

Secondly this paper was scheduled to appear one month earlier and the delay was beyond the control of either the author or the Secretary! The author's co-operation in turning round proofs inside a couple of days is gratefully acknowledged.

Since I have started with some general comment I would now like to turn to the content of the paper. I know the author considers me to be something of a Luddite with regard to some of his proposals – I prefer the term realist.

As engineers we are confronted by masses of available information – a veritable explosion of facts in books, papers, journals and other forms. Any system which can provide a key to ensuring that the best use is made of accumulated knowledge must lead to better decisions. Recognising that optimisation routines can be built in to take account of uncertainty some judgement remains the domain of the engineer.

Human error is largely the result of the exercise of incorrect judgement but it is not only operators who commit such acts. Most forms of failure can be traced back to humans making mistakes. So the use of expert systems can improve the situation by providing "advice" based on stored knowledge.

However there is a dilemma – the long stop remains the human and yet he is now sheltered from all except the extreme decisions. It is an old story. In automation it leads to airline pilots sitting back watching an aircraft flying itself and yet they are expected to be able to take over and operate manually in emergencies. Errors result due to lack of continuous updating of the individual's memory. How can expert systems be introduced so that the human does not become locked out of a large proportion of decision making and, effectively, deskilled yet still required to be the real expert when the system reaches its limits. We all acquire knowledge in making minor decisions of minimal consequence. Could the author explain how he would arrange a system for fault diagnosis on a main engine so that the engineer seeking corrective instructions did not become blinded by the machine but made best use of its automated advice?

Furthermore the knowledge base of industry is not static but changes with time. New data modifies old tenets. How does one deal in a rule making expert system with deletion of obsolete information?

I would observe that at the recent ICMES '87 Conference held in Sweden there was a long debate about the future direction of marine engineering. One school backed ultra sophistication and maximum use of computers. The other back simplification for reliability and reduced maintenance. Where will the truth lie?

How does the desk top guru fit into the Society's future? The author has outlined some possible applications but has declined to predict the answer. There is obvious scope for using expert systems particularly in areas where "experience" and past precedents are paramount. On the other hand the Society will be called upon to approve installations which depend on the use of expert systems and artificial intelligence. Could the author comment on the effort required to develop the necessary capability and give his views on the priority areas for application.

From Dr. J. Newland

How realistic and viable is the eventual commissioning of a working General Marine Technology Expert System on-board ship?

Commentary

This would have to take into account the software specification, programming and implementation, hardware specification, as well as rigorous testing and then training needs.

In addition, the cost of such a system is likely to run into hundreds of thousands of pounds and many man-years effort.

Given the complexity of some of the Specific Marine Technology Expert Systems described in section 6.2, it is clear that these systems would not be able to operate in actual real time.

Therefore, can you give rough estimates as to the effect 'real' time involved in taking snapshots of the sensor values and comment on the effect this would have on the performance of the expert systems?

From Dr. R. Nataraja:

I would like to congratulate the author for an excellent introduction to this topical yet eluding subject of AI systems. Over the last ten years considerable effort has been expended on developing languages and expert systems in a variety of fields. The possibilities for expert systems are unlimited and the versatility of such a system is only limited by the imagination and ingenuity of its designer. With the advent of modern large fast parallel processors integrated AI systems are becoming a reality. Nevertheless the design of a sophisticated AI system is complex as highlighted by the author. The success of an AI system depends largely on the availability of consistent heuristic data and reliable raw data amenable to logical manipulation. I would welcome the author's comments on the existence of such

data in specific fields of interest to the Society. His suggestions on formalisation acquisition of such data would also be appreciated. Operational and maintenance aspects of the expert system also need consideration. The end user, I would consider as the most important element followed by the environment in designing and using an expert system. The system should also cater for emergency scenarios. In the absence of any heuristic knowledge how could this be simulated in an AI system?

It is clear that there are several levels of expert systems. On the simplistic level deterministic evaluations from analytical models have been the basis of engineering and other designs. Techniques such as fault tree analysis, hazard/consequence analysis etc. may be considered to be at the second level. Probabilistic methods form the next higher level. AI systems perhaps form the highest level. In this classification there is a progression from analytical methods based on the physics of the problem to synthetic method which is rule based. It is this aspect that makes the AI system expensive and difficult to comprehend unless complex analytic models are replaced by simple empirical models. I would like comments from the author on this aspect.

From Mr. J. T. Stansfeld:

The second half of the paper describes the application of artificial intelligence techniques to marine activities in the future. Expert systems to assist in the design and operation of ships are described in some detail. Figure 6 refers to a range of applications traditionally outside the scope of the Society's activities. Whilst these areas may become more important in the future I would like to ask the author, and perhaps other members of staff present, what consideration has been given to the introduction of knowledge-based systems for current activities. It would appear that the structure of the Society is ideally suited to the exploitation of this technology with specialists in HQ consulted on specfic matters by staff from the outports. Some departments spend a large amount of time responding to queries from outports. If the knowledge of the specialists could be expressed in knowledge-based systems these could be made available to the outports on discs for use in a desk top computer. This would not mean replacing the expert, rather making this knowledge more widely available to enable the surveyor to offer a faster response to the client. The specialist spends less time answering queries which may seem to be routine and therefore has more time to enhance his knowledge. There are many such advice or decision support systems in operation in other organisations.

The two expert systems being developed for fuel characterisation and fault diagnosis will contain rules induced from data, which are presumably exact, and rules from heuristics expressing the knowledge of experts which may be qualitative or subjective. Are there any problems in combining these two types of knowledge in the same knowledge base?

AUTHOR'S REPLY

To Mr Pomeroy:

With reference to the historical events leading to the preparation of the paper, the help from the IRTA secretary was a major factor in achieving the time schedules. I would like to thank Mr Pomeroy for the interesting points he has raised. The comments indicate progressive views; rather opposite from those of a 'Luddite'. We can start therefore, discussions from a mutually shared belief that a realistic R&D programme in AI is the key to future progress in this area.

The first major issue raised can be summarised under the question: 'What can be done to avoid excluding humans from decision making?' Storing knowledge, optimisation and uncertainty are further aspects in this area.

A fundamental principle, that is common belief between many researchers in AI, is that the introduction of expert systems will be in the role of advisor; the decisions will be taken by humans. To ensure that this principle can be properly implemented, two routes can be pursued:-

(a) The design equation of AI based systems must include the human in an interactive role. Details will be application dependent.
(b) Users of expert systems must be specially educated and trained for the proper use of this technology.

Storing accumulated knowledge and 'distilling' what is necessary for a particular request, is obviously feasible with existing techniques. Uncertainty can be dealt with by estimating confidence levels. The expert system will therefore give advice with an appropriate estimate of 'confidence level' attached to it. Human decision can then be based on an informed picture of the situation.

The next question is another important issue. 'We all acquire knowledge by making mistakes.' This is a learning process which can be retained with expert systems. The only difference will be that when the wrong decision is made, the system could eliminate any costly consequences. The implication of an erroneous decision will be assessed and an explanation can be given to the user in light of the available information.

In the fault diagnosis expert system that was described in the paper, the actual techniques being used provide an explanation of 'how the engineer seeking corrective instructions does not become blinded by the machine'. Faults are represented as objects with the following attributes:-

Type:	A description of the fault.
Severity:	Some measure of the fault severity.
Exists:	A boolean value which is set TRUE if the fault is confirmed.
Explanation:	A detailed explanation of the way the fault was deduced.
Certainty:	A probability value associated with the diagnosis.
Proof:	Call a simulation model.

The 'proof' attribute requests the execution of an engine model which can validate the fault condition diagnosed by the system. The same model can be used to identify the implication of any fault which the operator may think is present in the engine.

The knowledge base of industry is clearly not static. The development environment which has been proposed in the paper takes this into account. In fact we have a collaborative research project which concentrates in the 'rule validation and maintenance' aspect.

Validation is needed at two levels:-

(a) Ensuring the consistency and correctness of the data used (input validation).
(b) Ensuring the general applicability of the induced rules (output validation).

Input validation is undertaken manually by experts. For the output validation a special 'Rule Validation Software' package RVS is being developed. The RVS is used to establish whether the information used to produce the rules is incomplete. If it is, the RVS identifies the non-specified set of conditions. These conditions are then tested against the decision rule. Experts are then asked to endorse or reject the decision values obtained. The rule is updated and the validation process is completed.

Apart from rule validation, a maintenance system is necessary for updating automatically the effects of new technology.

To do this, it is necessary to translate the decision tree to an information database which preserves the generalisation of the initial decision rules. The new information is then added in this database from which a new decision rule is produced.

With regard to the future direction of the marine industry, my personal views are clearly stated in the conclusions of the paper. I hope that 'simplification' for improved reliability and reduced maintenance can be achieved by correctly using new technology. In this respect Lloyd's Register has the capability to guide

the industry towards that goal.

To Mr. Stansfeld:

The final question from Mr Poneroy raises the same points emphasised by Mr Stansfeld. The question is 'how expert systems fit into the Society's present and future?' I believe that there are four distinct applications for Artificial Intelligence technology in the Society. In order of priority these are:-

(a) Application within the Society's current activities.
(b) Assessment of complex integrated control or monitoring systems based on expert systems.
(c) New Information Technology services.
(d) Consultancy in the development of expert systems.

The Lloyd's applications can be subdivided into two areas. First there is substantial scope to use expert systems within technical departments where 'experience' and past precendents are paramount. This would improve the efficiency of the technical departments and will safeguard retaining the cumulative knowledge of experienced surveyors. We are currently developing such a system in collaboration with the ICD department. Other obvious applications can be found in departments such as Piping Systems and FOBAS.

The second application for knowledge based systems is in the outports. I agree totally with Mr Stansfeld that the structure of the Society, with specialists in HQ consulted on specific matters by surveyors from the outports, is ideally suited to the exploitation of AI technology. Indeed there is another important aspect in the collaboration between outport surveyors and headquarter specialists through knowledge base systems. The expert system development and maintenance can be driven by the requirements of the actual Lloyd's customers who communicate with the outport surveyors.

Validation of expert systems is an unresolved problem. Yet it is very important in two areas: (a) Validation of systems used internally by the Society's surveyors and (b) Independent assessment of expert systems. Independent assessment falls neatly within the framework of the Society's traditional activities. Certain aspects on rule validation have already been discussed. However, the wider issue of software and expert system validation, is a whole new subject for research and development.

On the question of combining rules induced from data with heuristics, possible difficulties are dependent on the development environment used. Environments such as MUSE are designed to allow integration of different rules. The object-oriented approach is particularly useful. An example which illustrates this point is given below:-

> The heuristic rule will be 'if maintenance has been carried out on a specific component then check this component first'

With reference to Appendix 2.4 the BCS Rule example will check if maintenance has been done before initiating the normal diagnostic process. During the diagnostic process observed deviation patterns are matched against 'fault prototypes'. These prototypes are a different representation of the rules induced from the experimental data.

To Dr. Newland:

With reference to comments made by Dr. Newland, it must first be clarified that the proposed 'General Marine Technology Expert System' is not intended for a ship-board application. I believe however, that such a system can be realised in Lloyd's Register or other large marine organisations. Shipyards with feedback from ship operation and even shipping companies can develop and utilise such systems. The realistic time scales before commissioning a working system will take optimistically a five year programme. Currently, the ESPRIT KBSSHIP project is estimated to use 100 man-years. The combined outcome of three such projects will be sufficient to address all the aspects described in the paper.

The second question relates to real time issues. This is particularly important for any overall ship management system. A number of distributed expert systems for voyage planning, loading, condition assessment, alarm handling etc. need to collaborate in real time to reach decisions.

Real time expert systems imply that the system function is time dependent. Also the 'state' of the world to which the system is applied is changing constantly.

There are currently many problem areas in real-time AI which are listed below:-

Detecting Changes

* How does the system detect interesting events?
* Is the event a value threshold or rate threshold?
* Does the interest in events vary over time?
* Will supporting data be needed?
* What is the time cost of information?

Response Requirements

* Minimum time response.
* Rating of time response for different critical events.
* Computational resource limits.

Interrupting Reasoning

* Priority assessment.
* Methods of interrupting the reasoning process.
* What happens to an interrupted process?

Consistency of Reasoning

* If the system is drawing conclusions from the state of the world on which it is acquiring data, and that state is changing, how does the system ensure that conclusions reached are consistent with the current state of the world?
* If a reasoning process has been interrupted and then resumed, how is the consistency of its interpretation affected by conclusions drawn by the interrupting process?

Our current R&D activities concentrate in three areas:-

(a) Consistency of reasoning.
(b) Interrupting reasoning.
(c) Planning in real-time.

Another important aspect in real-time is the development of parallel processors. The Society is collaborating with Bath University who for some years have been developing parallel computers. An application on diesel engine cycle simulation has been completed.

In this, an array of individual MC68000 computers were connected together using a specially designed parallel communication link. At present, a new form of multi-processor, based on the T800 transputer is being developed at Bath University with funding from the Department of Trade and Industry.

Specifically, on the question of required response time of the engine fault diagnostic system, two criteria apply. First, for critical parameters linked to alarms, a 30 second response time is required. This can be achieved by isolating the 'fast processing' part of the system from the slow part containing the simulation and expert systems. A dual processor arrangement is envisaged.

To Dr. Nataraja:

Dr. Nataraja highlights the need for consistent heuristic data and reliable raw data amenable to logical manipulation for building expert systems. Such data is not normally available in the Society. In the R&D projects described in the paper, the required data is being collected from purposely organised experiments. In other fields, such as offshore engineering, I

know that collaborative projects between universities and industry are aiming at collecting similar types of results from large scale experiments. The initial development process of expert systems, does in my opinion, require experimentally obtained results. Their formulation into structures easily analysed by other programs is described in paragraph 5.2.3.

Rules obtained from experimental data provide an initial platform for subsequent enhancements and refinements along the lines already described. The formal approach for the maintenance of expert systems has been outlined. I agree with Dr. Nataraja that the end user and the environment are important elements in designing and using expert systems.

Emergency aspects have not been dealt with in the paper. Many research projects are concentrating in this area. The main AI developments are in the real-time issues.

In all the expert systems described in the paper, three main sources of knowledge are used:-

(a) Rules induced from experimental data.
(b) Heuristics.
(c) Simulation models for validation and explanation.

In the absence of any of these three elements I would assume that the remaining two ought to provide sufficient information.

There are many classifications for expert systems and I would agree with Dr. Nataraja that AI systems may be considered complex and they are certainly expensive to develop. However, AI systems ought to be easy to comprehend from a user's viewpoint. It must be emphasized that in the expert systems described in the paper, analytical models, statistical analysis, induction rules and heuristics are all part of the system.

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ELECTRIC PROPULSION:

A REVIEW

B. P. Sharman

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Hon. Sec. R. V. Pomeroy
71 Fenchurch Street, London, EC3M 4BS

ELECTRIC PROPULSION: A REVIEW

by

B. P. Sharman



B. P. Sharman served his apprenticeship with the Admiralty at H.M. Dockyard, Chatham and subsequently spent 5 years with M.O.D. (Naval) as a Design Draughtsman/Technical Officer, gaining a B.Sc. degree from Woolwich Polytechnic during this period. In 1972 he joined Lloyd's Register and apart from 2 years in Montreal as Senior Electrical Engineer Surveyor for North America has been in HQ dealing with plan appraisal of electrical systems for ships and offshore installations.
He assisted Cunard in the technical appraisal of the electric propulsion systems, proposed by several manufacturers, for the passenger ship Queen Elizabeth 2, *carried out the Classification plan approval and performed inspection during manufacture on behalf of the main machinery sub-contractors.*

TABLE OF CONTENTS

1. INTRODUCTION

2. REASONS FOR ELECTRIC PROPULSION
   - 2.1 General
   - 2.2 Installation Flexibility
   - 2.3 Speed Variation
   - 2.4 High Torque
   - 2.5 Low Vibration and Noise
   - 2.6 Reduced Fuel and Maintenance

3. TYPES OF PROPULSION/THRUSTER DRIVES
   - 3.1 Driven Units
   - 3.2 Motors
     - 3.2.1 Direct Current
     - 3.2.2 Alternating Current
     - 3.2.3 Torque Considerations

4. ELECTRICAL SYSTEM CONFIGURATIONS
   - 4.1 DC Generators/DC Motors, Fixed Pitch Propellers
   - 4.2 AC Generators/AC Motors, Variable Frequency Generation and FPP
   - 4.3 AC Generators/DC Motors, Fixed Frequency Generation and FPP
     - 4.4.1 Fixed Motor Speed and CPP
     - 4.4.2 Variable Motor Speed and FPP

5. STATIC CONVERTORS
   - 5.1 Power Electronics
     - 5.1.1 General
     - 5.1.2 Silicon Controlled Rectifiers
     - 5.1.3 Gate Turn-off Devices
     - 5.1.4 Gate Triggering Arrangements
   - 5.2 AC to DC Convertors
   - 5.3 AC to AC Convertors
     - 5.3.1 Cycloconvertors
     - 5.3.2 Autosynchronous Inverters
     - 5.3.3 Auto/Forced Commutated Convertors
   - 5.4 Reversal Manoeuvres
   - 5.5 Convertor Transformers
   - 5.6 Thyristor Cooling

6 POWER SYSTEMS
   - 6.1 Centralised Generation
   - 6.2 Voltage Levels
   - 6.3 System Fault Levels
     - 6.3.1 Calculation of Short Circuit Currents
     - 6.3.2 Generator Reactances
     - 6.3.3 Back-up Fuses
     - 6.3.4 Bus-section Fault Current Limiters
   - 6.4 High Voltage Systems
     - 6.4.1 General
     - 6.4.2 Creepage and Clearance Distances
     - 6.4.3 Switchboards
     - 6.4.4 Current Interupters
       - 6.4.4.1 Air-break
       - 6.4.4.2 Vacuum
       - 6.4.4.3 Sulphur Hexafluoride
     - 6.4.5 Voltage Surge Diverters
     - 6.4.6 High Voltage Cables
   - 6.5 Electromagnetic Interference
     - 6.5.1 Radio Frequency Interference
     - 6.5.2 Harmonic Distortion

7 SURVEY AT MANUFACTURERS
   - 7.1 General
   - 7.2 Machines
     - 7.2.1 Rule Requirements
     - 7.2.2 Temperature Rise Tests
     - 7.2.3 High Voltage Tests
   - 7.3 Main Switchboard
   - 7.4 Static Convertors
   - 7.5 Cables

8. SOME NOTEWORTHY SYSTEMS
   - 8.1 Queen Elizabeth 2
     - 8.1.1 The Re-engining
     - 8.1.2 Central Power Station
     - 8.1.3 Main Switchboard
     - 8.1.4 Service Transformers
     - 8.1.5 Static Convertors
     - 8.1.6 Propulsion Motors
     - 8.1.7 Repairs and Maintenance
     - 8.1.8 Operation
   - 8.2 The SITMAR Passenger Cruise Vessels
   - 8.3 The Carnival Cruise Line Vessel
   - 8.4 The SUPERFLEX 2000 Ferries
   - 8.5 Crane Vessel for MICOPERI

9 ICEBREAKERS
   - 9.1 Operation
     - 9.1.1 Level Ice
     - 9.1.2 Ice milling
     - 9.1.3 Stalled Propellers
     - 9.1.4 Ice Ramming
   - 9.2 Canadian Coast Guard Icebreakers
     - 9.2.1 Type 1100 Nav-Aids
     - 9.2.2 Type 1200 Icebreaker
     - 9.2.3 Conceptual Polar Icebreaker

10 FUTURE DEVELOPMENTS
   - 10.1 Static Convertors
   - 10.2 Superconductivity

11. CONCLUSION

12 ACKNOWLEDGEMENTS

13 REFERENCES

14 BIBLIOGRAPHY

1. INTRODUCTION

Ships have been propelled and manoeuvred by electrical means for many years. The US Navy battleship *USS New Mexico*, built in 1917 had a steam turbine electric drive of 40,000 shp followed in 1919 to 1925 by five battleships having drives of 30,000 shp each and two aircraft carriers at 180,000 shp each. Electric propulsion was chosen to alleviate the problem of a national shortage of gearbox manufacturing capacity.

Mr. Horne[1] in 1931 makes reference to their being 128 vessels at that time having electric propulsion of various types. His paper also refers to some notable electrically propelled ships of the day such as the *Viceroy of India*, *Guaruja* and *Ipanema*.

During the second world war the US built some 300 plus surface warships with either 6000 shp diesel electric machinery or 12000 shp steam turbine electric propulsion, and for the merchant fleet, large numbers of turbo electric 'T2' oil tankers.

Over the years to date the popularity of electric propulsion has waxed and waned. At present there is a resurgence of interest, attributable partially to developments in power electronics, in the offshore field for highly controllable propulsion power for dynamic positioning and in the passenger ship field for combined propulsion and hotel service generation.

This paper discusses some of the electric propulsion options available related to various types of vessels for which plans are currently, or have recently been, considered in the Electrical Plan Approval Offices. Particular reference is made to the *Queen Elizabeth 2* re-engining, detailing some of the interesting electrical features, and to the Canadian Coast Guard (CCG) Conceptual Polar Icebreaker.

It may be noted that the Register Book does not truly reflect the Society's involvement in electrically propelled vessels as one of the world's largest electrically propelled fleets, that of the CCG, whilst it has been built under survey in compliance with the Society's Rules, is not maintained in Class. The Society does, however, have a close liaison with the CCG during any new building programme.

2. REASONS FOR ELECTRIC PROPULSION

2.1 General

Electric propulsion cannot usually be justified on purchase costs alone. It can easily be seen that to interpose an electric generator and motor between a low speed diesel engine and propeller to replace a relatively short length of shafting is not economic sense for the majority of cargo vessels.

For special types of vessels there are other reasons that may influence the selection of electric propulsion.

2.2 Installation Flexibility

The electric propulsion motor has a high efficiency and is compact. Unlike the diesel engine and steam turbine, it is not required to be connected to a multiplicity of pumps and pipework, and accordingly may be fitted in confined spaces. The connection to its source of power is by means of cables which in most cases are of smaller dimensions and more easily routed than pipework or shafting making it the obvious choice for mobile semi-submersible units.

A modern non-nuclear naval submarine is a good example of an electric propulsion system in a confined space. Apart from the breathing problems when the vessel is submerged, to achieve an equivalent diesel engine installation would require a long shaft line as the engine would have to be located in the broad mid-part of the submarine.

The electrical generating plant for the propulsion motor may be located in any convenient position on the vessel to maximise cargo space. In the case of the SUPERFLEX 2000 Ferries for Danish Owners, this is on the main deck. The number and size of generating sets are optimised to suit available space and are accessible for on-shore maintenance.

The low on-board maintenance requirement is very attractive to those who are operating tight sailing schedules with small crew. Repair is by replacement and should a propulsion motor be faulty it may be easily replaced by a spare with the minimum of disruption to the vessel's sailing schedules as the small electric units are easier to disconnect and remove from tank top levels for repair ashore than for a diesel engine or steam turbine.

2.3 Speed Variation

The speed of electric motors can be varied smoothly over a wide range, controlled to precise values and quickly altered. This may be used to advantage for vessels requiring frequent or accurate manoeuvring.

A vessel having dynamic positioning (DP) may use the precise motor control to advantage as in the case of the "MICOPERI Crane Vessel". Mr. Lough's paper[2] shows some typical DP arrangements. Geophysical and seismographical vessels such as the Petrocan *Bernier* uses electric motors to steer a precise path at a constant known speed to map the sea bed.

2.4 High Torque

Unlike the diesel engine, which does not develop useful torque until it reaches about 40% of rated speed, (Fig. 1) an electric motor, such as the shunt wound d.c. motor, can produce its maximum torque over 100% its speed range (Fig. 2).

High torque at very low speeds is required for icebreakers, which may have their propellers stalled by ice, and is also useful for vessels such as tugs.

2.5 Low Vibration and Noise

Transformers and static convertors are stationary and generators/motors rotate smoothly, provided they are correctly balanced, therefore vibration is minimal. Any reciprocating machinery such as the generator prime movers may be resiliently mounted with respect to the ship's structure to reduce the vibration normally associated with this type of plant. The generator may be mounted on a common bedplate with its prime mover, or solidly mounted and driven through a flexible coupling.

Very low vibration is generally demanded for the modern passenger ship whose customers pay for and expect accommodation equal to that of a top hotel. They do not expect to feel any effects from the ship's machinery.

The rotating electrical machine can be relatively quiet in operation. The propulsion motors for the *Queen Elizabeth 2* operate at a maximum speed of 144 rev/min and a conversation may be conducted alongside them in only a slightly louder than normal voice. At one metre from the motor the sound pressure level was measured on test at 83 dB(A).

Generating sets can be resiliently mounted and installed in acoustic hoods to produce a very quiet vessel. Applications for such vessels may include geophysical and seismographic survey and acoustic minesweeping.

2.6 Reduced Fuel and Maintenance

Having a minimum of moving parts, rotating a.c. electrical machines normally require the minimum of maintenance. This is increased in the case of d.c. machines, which need regular attention to their commutators and carbon brushes.

For vessels with large auxiliary loads and varied operational profiles, such as the maintenance and emergency support vessel *Iolair*, a centralised power generation arrangement can be adopted with the number and ratings of sets chosen so as to minimise fuel consumption and prime mover maintenance.

Nine generators sets are fitted in the passenger ship *Queen Elizabeth 2* feeding two propulsion motors. These replace a steam turbine installation. After extensive evaluations, the diesel-electric installation provided optimum reliability and flexibility combined with minimum operating costs.

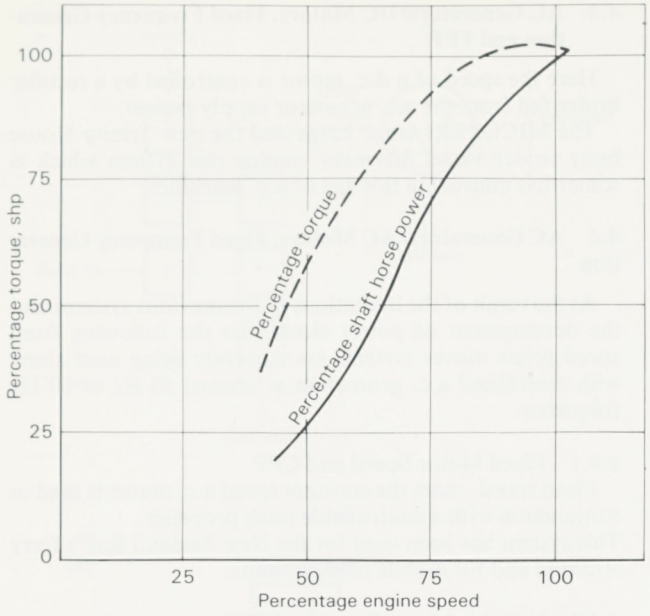


Figure 1 Typical Diesel Engine Performance Curve

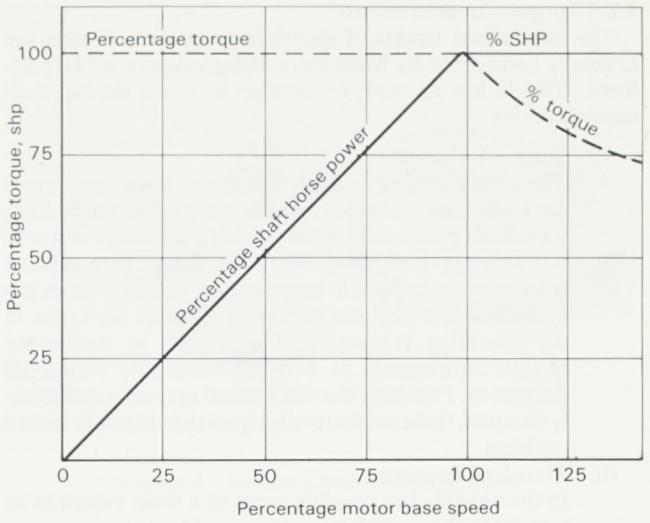


Figure 2 Typical DC Shunt Motor Performance Curve

3. TYPES OF PROPULSION/THRUSTER DRIVES

3.1 Driven Units

There are a number of ways the power from an electric motor may be transmitted to propel or manoeuvre a vessel:

(a) by direct means or through a gear box to a conventional fixed pitch propeller (FPP) or to a controllable pitch propeller (CPP)
(b) by an azimuthing or fixed ducted propeller assembly
(c) by a cycloidal propeller assembly
(d) by hydrojet thrusters.

For a FPP the speed of the electric motor must obviously be variable and for a CPP may be constant.

Steering of the vessel may also be achieved by the propulsion unit as in the case of the azimuthing propeller assembly. Where such arrangements are the sole means of steering, vessels that would conventionally have a rudder stock of over 230 mm would be required to have an emergency means of steering in compliance with Part 5, Chapter 19.6 of the Rules[3] and SOLAS. Such vessels are specially considered in HQ.

It is worthy of a mention that in addition to being used as a propulsion unit some hydrojet thruster systems such as the "OMNITHRUSTER" may also be arranged to incorporate a bubbler system to lubricate the hull and ice interface of an icebreaker to reduce friction and assist passage.

The electric propulsion unit may be used as the sole means of propulsion or in conjunction with direct drives. Such arrangements have been used for fast patrol boats and warships whereby electric motors are used to conserve fuel for loitering on patrol and high speed diesel or gas turbines to give boost power for high speed pursuit.

There are also vessels which have the facility of operating the main propulsion "power take off " generator as a motor, for a "get you home" mode fed from an auxiliary generating set.

3.2 Motors

3.2.1 Direct Current

DC motors have the versatility of speed variation, reversal and high torque at low speed. Their disadvantages, compared with a.c. machines, are higher construction costs and brush-gear/commutator maintenance.

DC propulsion with convertors has been chosen for the RN Type 23 frigates on the basis of established reliability. There is however an empirical limit to the size of d.c. motor that can be built based upon the product of speed and power. The limiting formulae is:

power (kW) $\times$ weak field speed (rev/min) $\times$ field weakening ratio $= 6.7 \times 10^6$.

With a field weakening ratio of approximately 4 this may be simplified to:

power (kW) $\times$ normal speed (rev/min) $= 1.5 \times 10^6$ which in real terms equates to a 10 MW motor with a speed of 40 rev/min.

3.2.2 Alternating Current

Alternating current motors can be operated at variable speeds, started on load and run up to a desired speed by feeding their stator with a variable frequency. Motor speed is proportional to frequency/number of poles:

$$\text{rev/min} = \frac{120 \times \text{frequency (Hz)}}{\text{number of poles}}$$

The synchronous motor is used in preference to the asynchronous induction motor for many applications, although the induction motor is simpler and cheaper. This is because it may be manufactured with larger air gaps than the induction motor making it more suitable to withstand arduous mechanical conditions and a degree of bearing misalignment due to the ship's flexibility.

The synchronous motor operates at a unity power factor over its entire load range. At the maximum output of the cycloconvertor the ships supply power factor is claimed by manufacturers to be between 0.6 and 0.8 and this reduces at lower loads. Thus overall system efficiency is higher and installed generator VA requirements less with synchronous motors than with the asynchronous type.

Asynchronous motors in the form of caged rotor induction motors are used for low powered propulsion systems but for larger installations and where high torques are encountered synchronous motors are favoured.

There are two types of static convertors that may be used to feed synchronous machines variable frequencies from a fixed frequency supply, the cycloconvertor and the autosynchronous inverter. Both are reversible and are able, if necessary, to brake the motor.

Caged rotor induction motors are generally fed by autocommutated or forced commutated inverters, although cycloconvertors may also be used.

3.2.3 Torque Considerations

The mechanical aspects of electrical propulsion systems are normally considered by Machinery Design Appraisal Department. The following may be bourne in mind during such considerations.

(a) Torque Pulsations
The motor currents of the 'd.c. link' static convertors have a square waveform which means that the voltage waveform produced by the propulsion motor stator is not rotating smoothly, but is jumping. In a 6-pulse convertor the magnetic motive force jumps 6 times per cycle, and in a 12-pulse convertor 12 times per cycle, at the operating frequency. This results in oscillatory torque components at 6 or 12 times the rotational frequency. Provided the mechanical system is sufficiently damped, these oscillatory torques should not present a problem.

(b) Transient Torques
In the unlikely but possible event of a short circuit at its terminals, the propulsion motor would act as a generator and supply short circuit current into the fault. This sudden change would produce a transient oscillatory torque. A recent study of such a condition on a vessel by the Society's Advanced Engineering Services revealed that the frequency of such a disturbance when considered in relation to the shafting system gave rise to high enough transient torque to possibly shear the shaft.

4 ELECTRICAL SYSTEM CONFIGURATIONS

4.1 DC Generators/DC Motors, Fixed Pitch Propellers

(a) Series connected system – here the generators and motors are connected in series in one circuit. Control of speed and direction of rotation of the propulsion motors is accomplished by varying the generator excitation and motor fields.

(b) Parallel connected system – here the generators are arranged to operate in parallel to supply the propulsion motors. Control is achieved in a similar manner to the above.

Both the above systems have been used widely in the past particularly for icebreakers and are well proven. As with all d.c. machines the motors have carbon brushes and the selection of the correct grade of electrographitic brush to cover the full range of power demands and minimise the build-up of carbon dust in the machine has always been a problem.

These systems also require a separate generation system for the auxiliary a.c. services.

4.2 AC Generators/AC Motors, Variable Frequency Generation and FPP

Here a synchronous motor is supplied by a generator driven by a gas or steam turbine. Speed control of the propulsion motor is achieved by varying the speed of the prime mover i.e. the system frequency.

Such a system has been successfully employed for some 25 years in the passenger ship *Canberra*.

An adaptation of the above variable speed prime mover a.c./a.c. drive is still occasionally used for athwartship thruster systems. One of the diesel engine driven ship service generators is arranged to be connected to the bow thruster electric motor, with both at standstill. The prime mover and motor are started together. Because of prime mover limitations it is difficult to achieve high torques at low propeller speeds with this configuration.

4.3 AC Generators/DC Motors, Fixed Frequency Generation and FPP

Here the speed of a d.c. motor is controlled by a rectifier bridge fed from the a.c. generator supply system.

The MICOPERI crane barge and the new Trinity House buoy tender vessel *Mermaid* employ this system which is somewhat unusual in this age of a.c. machines.

4.4 AC Generators/AC Motors, Fixed Frequency Generation

As the result of the limitations of the previous systems and the development of power electronics the following fixed speed prime mover systems are currently being used along with centralised a.c. generation at normal 50 Hz or 60 Hz frequency.

4.4.1 Fixed Motor Speed and CPP

Fixed speed – here the constant speed a.c. motor is used in conjunction with a controllable pitch propeller.
This system has been used for the New Zealand Rail's ferry *Arahura* and for mobile offshore units.

4.4.2 Variable Motor Speed and FPP

Variable speed – here the speed of an a.c. motor is controlled by a frequency convertor and is generally used in conjunction with a fixed pitch propeller.

This is now the most widely used system for many types of vessels which include icebreakers, mobile offshore units, passenger ships and ferries. *Queen Elizabeth 2* uses an adaptation of this system with a controllable pitch propeller and a combinator control which adjusts both the pitch of the propeller and the speed to the motor to achieve optimum operating conditions.

5 STATIC CONVERTORS

5.1 Power Electronics

5.1.1 General

The new generation electric drives have been brought about by the development of reliable high power semiconductor devices and their control systems.

Power electronics dates back at least 40 years. These circuits were first implemented using thyratrons and mercury-arc rectifiers for the high currents with vacuum valves (or tubes) and magnetic amplifiers for control. The development of solid-state semiconductor devices such as thyristors, transistors and integrated circuits has given the old technology new relevance.

Transistors and integrated circuits are used for the control circuitry either in the form of discrete components or as part of microprocessor or electronic programmable controller as described by Finney[4].

The power control devices are called 'Thyristors' and within this family of special devices are:

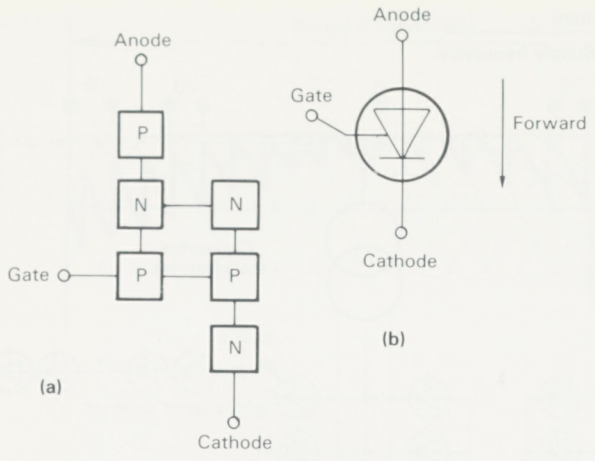
(a) Silicon Controlled Rectifiers – SCR's
(b) Gate Turn-off Devices – GTO's
(c) Triacs
(d) Diacs

Triacs and Diacs are generally used for lower power control, an example of which is the domestic light dimmer.

SCR's and GTO's are the devices commonly used for high power control. Their operation is basically the same.

5.1.2 Silicon Controlled Rectifiers

An SCR is a four layer semiconductor device with alternating layers of p-type and n-type semiconductor material. Fig 3a shows the junction schematic and Fig 3b the circuit symbol. Modern semiconductor development has resulted in these



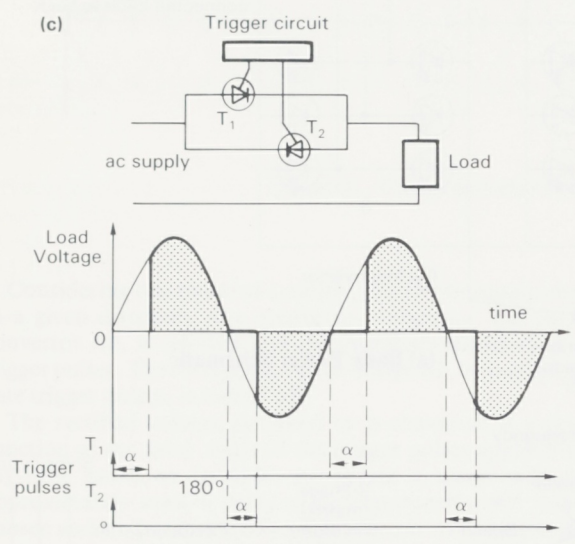


Figure 3 The Silicon Controlled Rectifier

devices becoming very robust, reliable and capable of handling high currents and voltages. The SCR's used in static convertor drives may be likened to an ice hockey puck, Fig 4. The semiconductor device is encapsulated in a case one face of which is the anode (– ve) and the other the cathode (+ ve) with the gate normally being brought out as a connection on the side.

The thyristor on the far right of Fig. 4 is of the type used for the convertor for *Queen Elizabeth 2*. It is 75 mm diameter and 26 mm thick and has a rating of 1650 Amp rms value.

The Rules do not have any detailed requirements for SCR's but they would be expected to meet IEC Standard 92-501[5] Section 12.

The SCR's are connected in series to make them suitable for high voltages and in parallel for high currents. For example, the static convertors for *Queen Elizabeth 2* are rated at 11 MW at 10 kV and each of the 6 arms of the 2 bridges is made up of single legs with 12 SCR's connected in series, making a total of 144 SCR's. If a cycloconvertor were to be used for *Queen Elizabeth 2* instead of the autosynchronous inverter a total of 216 SCR's would be required.

An SCR acts in a manner similar to a diode in that it conducts current easily one direction but blocks it in the other direction. It will not, however, conduct in the forward direction until a trigger current is applied to the gate. It will then conduct current, without the continuation of the gate trigger current,

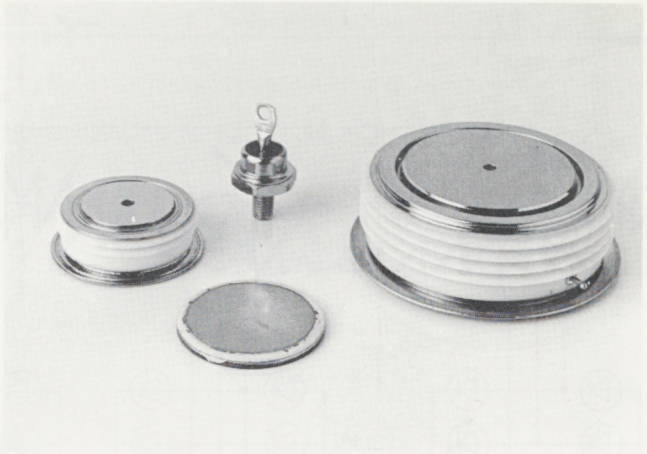


Figure 4 Silicon Controlled Rectifiers

until either the anode current falls below a critical value or the anode voltage is reversed. The SCR will then stop conducting i.e., is turned off or "commutated". The triggering of the gate current can be delayed by various angles as shown in Fig 3c in order to control the mean voltage output.

5.1.3 Gate Turn-Off Devices

The GTO differs from ordinary SCRs in that they can be turned off with a negative current pulse on the gate. This facility may be used to advantage when fast, precisely controlled, switching is required. They may also be used where forced commutation circuits are required making such circuits less complicated.

5.1.4 Gate Triggering Arrangements

The thyristor gates are normally triggered by supplying them with a current pulse either directly from an electronic pulse generator or, in the case of high voltage bridges, indirectly using a pulse transformer.

Instead of the electrical wire the gate connection may be an optical fibre, with the triggering pulse being a light signal. In these cases special opto-thyristors are used which have a light sensitive semiconductor gate, but would otherwise operate the same as a normal device. This arrangement is used, as with the pulse transformers, to obtain segregation between signal and high voltage circuits. Optical fibres are also insensitive to

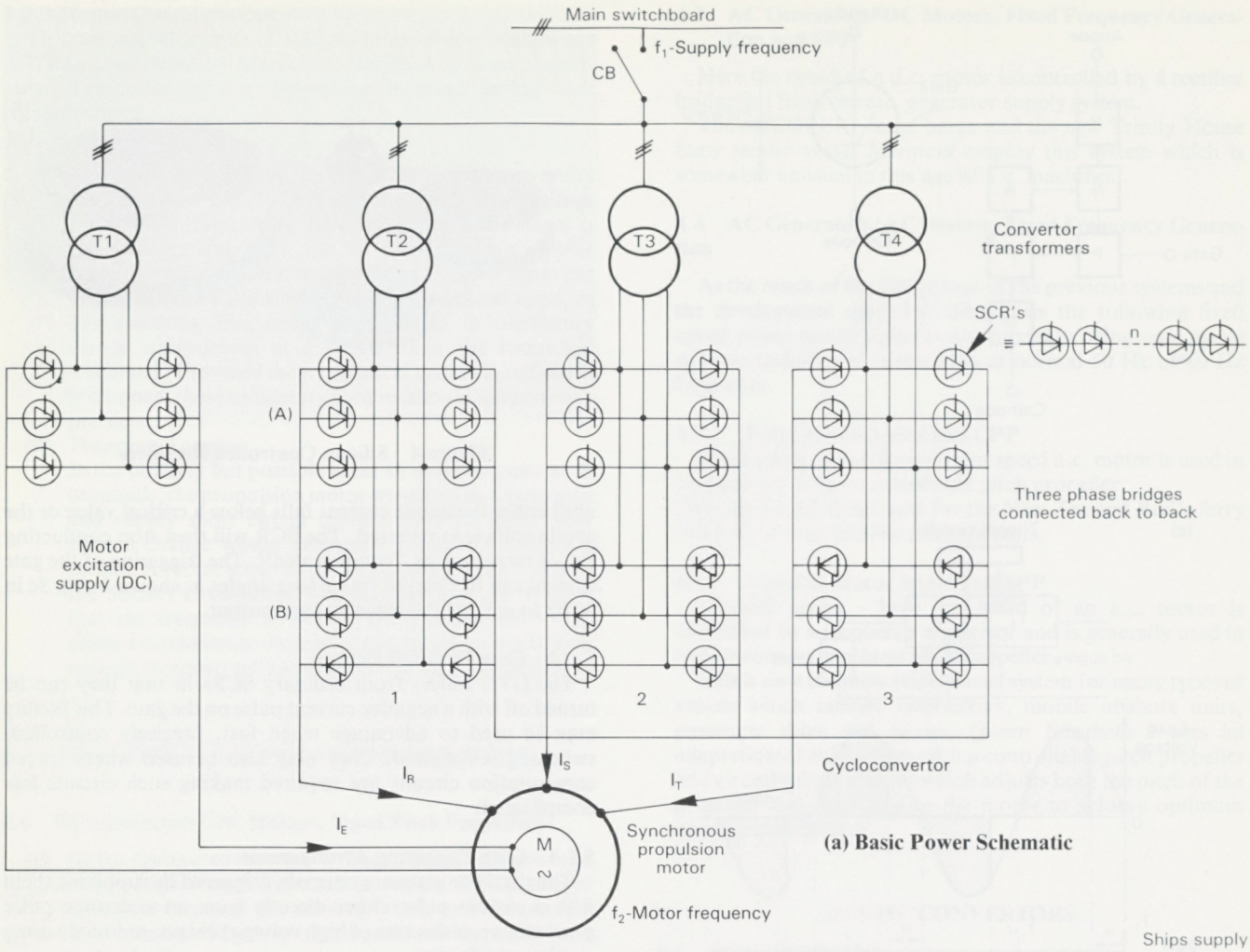
5.2 AC to DC Convertors

These are the simplest type of convertors and are designed to supply a d.c. motor armature and/or field with a stepless variable voltage automatically controlling its operation. The bridge arrangement is essentially the same as that of the supply bridge for the autosynchronous convertor with a 3-phase "Graetz" bridge supplying the d.c. motor armature.

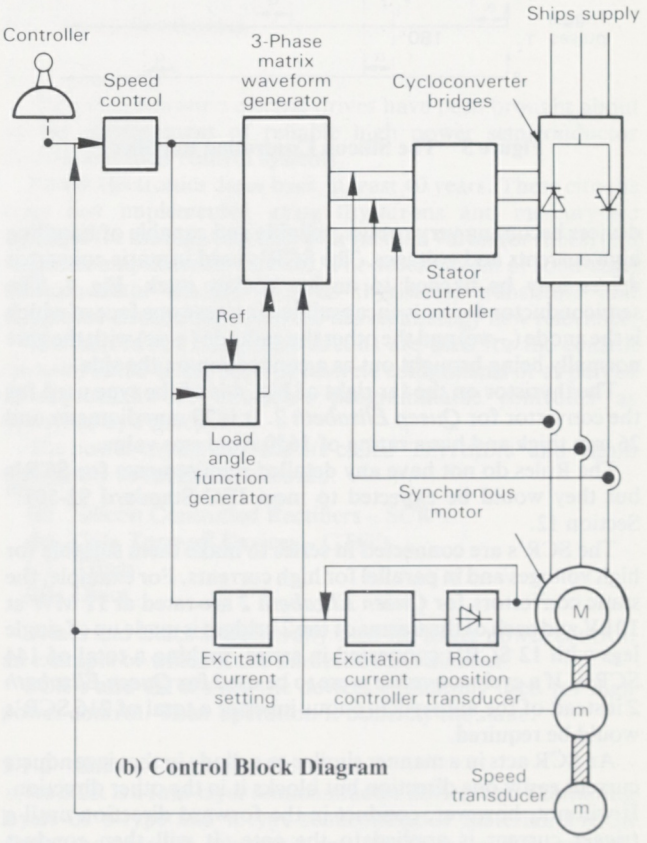
The Graetz bridge is fully-controlled and is normally of the six-pulse type. The output voltage is varied by sequentially firing the thyristors at differing phase angles. A rippled output voltage waveform is obtained which when applied to the inductive circuit of a d.c. machine is smoothed out to give mean direct current and a steady torque.

The shunt field of the motor generally is supplied separately either at a constant voltage, from a simple rectifier excitation unit, or at a variable voltage from a thyristor convertor excitation unit, when constant power operation of the motor is required. Speed may be varied by both armature voltage and field control.

Convertors supplying unidirectional motors generally have a normal series/parallel connection for the thyristors to give uni-directional current. For reversible motors thyristors are connected back-to-back to reverse the current.



(a) Basic Power Schematic



(b) Control Block Diagram

Figure 5 Cycloconvertor Fed Synchronous Motor

DC convertors have an advantage that they are smaller than an a.c. convertor of equivalent rating and therefore where space is at a premium, and a d.c. motor is acceptable, they may be preferred.

5.3 AC to AC Convertors

5.3.1 Cycloconvertors

The principle of the cycloconvertor has been used since the 1930's when they were employed to obtain the frequencies of $33\frac{1}{3}$ and $16\frac{2}{3}$ Hz for railway traction.

The changing of the fixed frequency from the ships supply network into the variable frequency feeding the stator of the synchronous propulsion motor is a direct conversion in that there is no d.c. link in the SCR bridge as in the case of the autosynchronous inverter.

Figure 5a shows the basic diagram of the power section of a cycloconvertor fed synchronous motor. Each phase of the motor is connected through back-to-back Graetz bridges to the supply network via transformer windings. The transformers may be individual units or a single unit having a 3 phase primary and 3×3 phase secondary windings.

To understand its operation, one phase of the cycloconvertor may be considered supplying a single phase load. Each bridge supplies current in one direction only, so in order to obtain a complete sinusoidal wave two bridges connected back-to-back are required.

The operating bridge determines the direction of current and the delay angle control of the thyristors determines the direction and magnitude of the output voltage. In order to prevent circulating current between the bridges a delay is necessary at each polarity change.

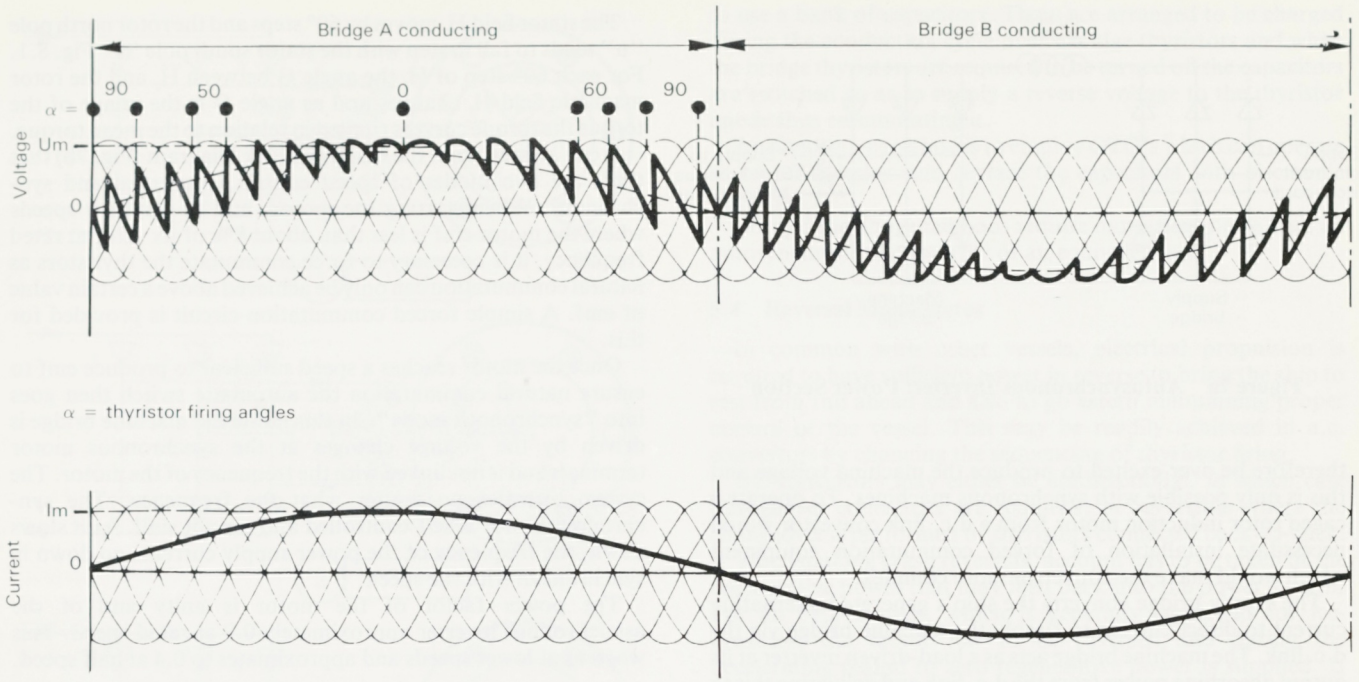


Figure 6 Cycloconvertor Output Phase Voltage and Current Waveforms

Considering one phase of a motor, in order to supply current in a given direction, one convertor bridge, i.e. the forward convertor A1, is selected and the thyristors are fired by gate trigger pulses. The reverse convertor bridge B1, by not being fed gate trigger pulses, is locked off.

The rectified voltage delivered by a convertor is a reverse function of the delay angle of the trigger pulses applied to the thyristor gates, so in order to obtain a mean voltage of approximately zero, a delay angle approaching 90° must be chosen and by decreasing this angle towards zero the maximum rectifier voltage may be obtained.

To obtain the trigger pulses an electronic waveform generator is used. (Fig. 5b). This is programmed to fire the thyristors sequentially with the appropriate trigger pulse delay angle so as to build up the output voltage in the form of an envelope curve or cycloid using selected segments of the input voltage waves (Fig. 6). This cycloid has a different frequency and amplitude to the input voltage. It is the aim of the system designer to approximate this output cycloid to a sinusoidal wave.

To obtain the complete single phase output waveform, each convertor bridge is fired sequentially and to obtain a three phase output to feed the motor each leg of the convertor is arranged to operate with an angle of displacement of 120° between them.

Theoretically, it is possible for the cycloconvertor to supply voltages at any frequency between zero and the ship's supply frequency. However, above one third of the supply frequency some legs of the convertor bridges stop conducting because of constraints of the thyristor's operation. In an extreme case only one branch of the convertor bridge may conduct and as it is not possible to determine which branches would conduct the most, all the thyristors would have to be overrated to take account of the maximum load that they may carry. At the supply frequency this overrating ratio may be a factor of 3.

Up to one third of the ships supply frequency all the thyristors operate in a similar manner with the same currents for the same duration for the same recurrent cycles. Therefore for economic reasons the output of a cycloconvertor is generally limited to one third of the ships supply frequency. For a ship having a ships supply frequency of 60 Hz the maximum cycloconvertor frequency would be 20 Hz. However, the manufacturer generally limits this even further to 18 Hz, as the quality of the output waveform may deteriorate above this frequency.

The figures show a 6 pulse bridge connection but a 12 pulse convertor bridge could equally be used. However it would require twice the number of thyristors, thus making it a more complicated arrangement. A 12-pulse convertor has an advantage in that the 5th and 7th harmonics, which give rise to additional heat losses in electrical equipment, are not present.

If the output frequency was controlled within fine limits at any one fixed value and the synchronous motor were to be subjected to a sudden load change, as would be expected during ice breaking operations, the motor would fall out of synchronism. To avoid this, the convertor is so controlled that its output frequency varies with the speed and rotor angle of the synchronous motor. This is achieved by transducers on the motor shaft feeding actual speed and rotor angle back into the control system. (Fig. 5b).

Provision may also be made to control and limit the motor output torque so that irrespective of the speed demanded by operator, the control system will only permit the speed at which the motor torque is equal to the load torque. The characteristic obtained would therefore be similar to that for a d.c. motor. (Fig. 2).

5.3.2 Autosynchronous Inverters

Originally used some 10 years ago for soft starting large synchronous motors the autosynchronous or load commutated inverter is now used widely in land based industry for speed control of large pump and compressor drives. The system is available from a number of manufacturers under various trade names. It is also referred to as a synchro-drive or sync-drive.

The frequency conversion is indirect in that there is a direct-current link between the two bridges. The convertor has a main input circuit which is a line-commutated controlled rectifier, a current controlled d.c. link which includes a smoothing reactor and an output machine-commutated inverter. Both bridges are identical (Fig. 7a).

Both the supply (input) bridge and the machine (output) bridge are commutated externally by the ship's supply voltage and synchronous motor voltage respectively. The motor must

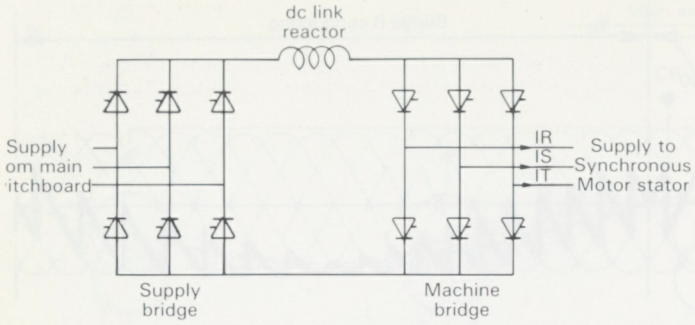


Figure 7a Autosynchronous Inverter: Power Section

therefore be over-excited to produce the machine voltage and this is only possible with synchronous machines. To operate a caged rotor induction motor from a d.c. link convertor would necessitate installation of forced commutation equipment which would make the convertor more complex.

The supply bridge converts the ship's generated alternating current to direct current to supply the machine bridge via the d.c. link. The machine bridge acts as a load-driven inverter at its output absorbing power from the d.c. link and delivering this to the machine.

It can be said figuratively that the machine bridge follows the motor in that it is the commutating frequency of the motor that determines the commutating frequency of the bridge. The system closely resembles that of the d.c. motor drive and has been referred to as the "electronic" d.c. machine where the "mechanical" commutator has been replaced by the electronics of the inverter.

The operation of the sync drive is shown in Fig. 8. The stator field H_s is that produced when the respective thyristors are triggered. H_r is the field produced by the rotor.

The rotor position, which is given by the rotor position transducer. (Fig. 7b), is fed to the control circuits which initiates the triggering of the appropriate thyristors to switch the current from the link to the adjacent motor phase causing the rotor to rotate. The thyristors are then sequentially triggered switching the current from one motor phase winding to the next.

The stator field H_s moves by 60° steps and the rotor north pole "n" tends to fall in step with the stator south pole "s" Fig. 8.1. For each 60° step of H_s the angle Θ between H_s and the rotor magnetic field H_r changes and as angle Θ is the image of the torque the torque curve is rippled in relation to the mean torque.

It can be seen from the Control Block Diagram (Fig. 7b) that there are two modes of speed control, sequential and synchronous. When starting the motor, and at very low speeds where the motor emf is less than about 8% of its value at rated frequency, it is necessary to force commutate the thyristors as natural commutation can only be achieved above a certain value of emf. A simple forced commutation circuit is provided for this.

Once the motor reaches a speed sufficient to produce emf to ensure natural commutation the automatic switch then goes into "synchronous mode". In this mode the machine bridge is driven by the voltage changes at the synchronous motor terminals and is not linked with the frequency of the motor. The system operates no matter what the frequency. The synchronous motor is self-controlled and cannot stall. As it slows down, the frequency of the power supply currents go down in synchronism with the speed.

The power factor of the motor is unity and of the asynchronous inverter approximately 0.9 at rated speed. This worsens at lower speeds and approximates to 0.4 at half speed.

5.3.3 Auto/Forced Commutated Convertors

Asynchronous caged rotor induction motors may be started or driven by these convertors. The motor could operate at rated speed in conjunction with a CPP, or alternatively, operate at variable speeds in conjunction with a FPP. For the latter the convertor would be rated for the full load of the motor, whereas the starting duty convertor would normally be short time rated for the starting current at a nominal no-load, i.e. with the CPP at zero pitch.

The convertor may take a similar form to an autosynchronous convertor having an input bridge, d.c. link and a machine bridge. Commutation of the input bridge is done by the ship's supply. As the asynchronous motor does not produce a machine voltage until it reaches about 60% of its rated speed other means have to be provided to commutate the thyristors until this speed is reached.

One method of commutating the machine bridge thyristors is

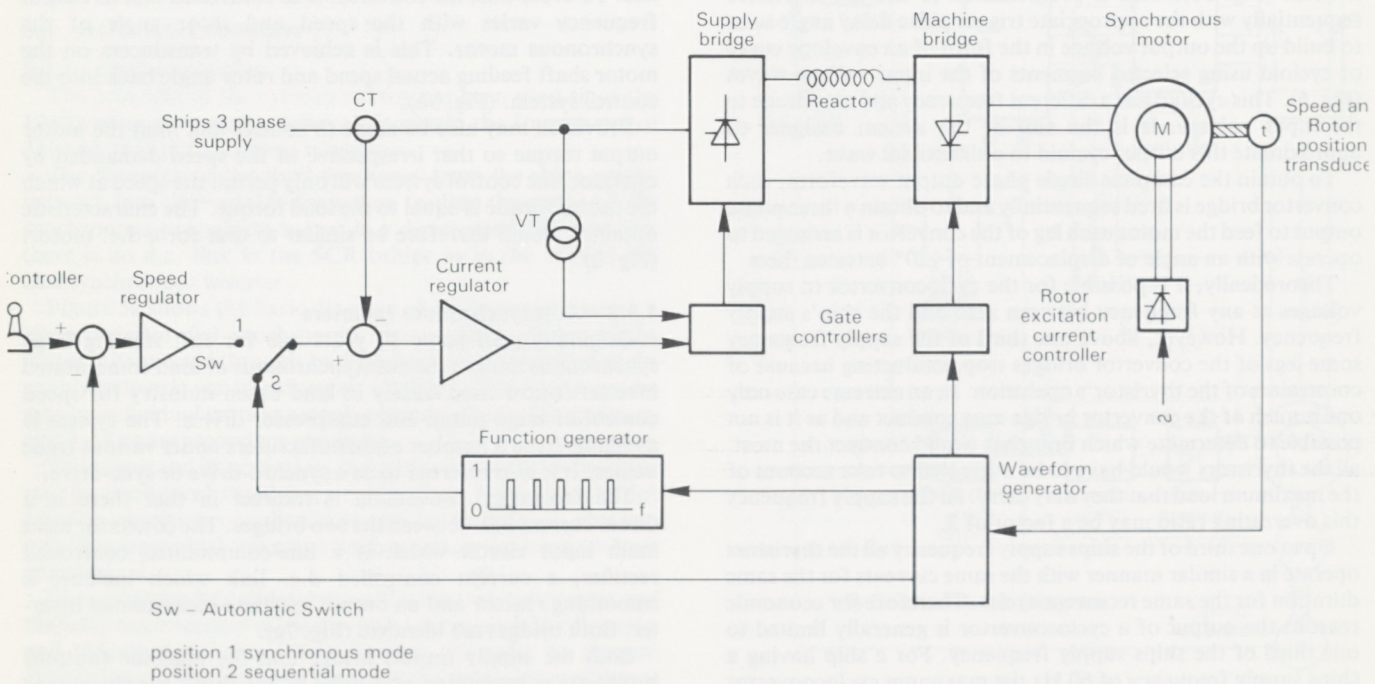


Figure 7b Autosynchronous Inverter: Control Block Diagram

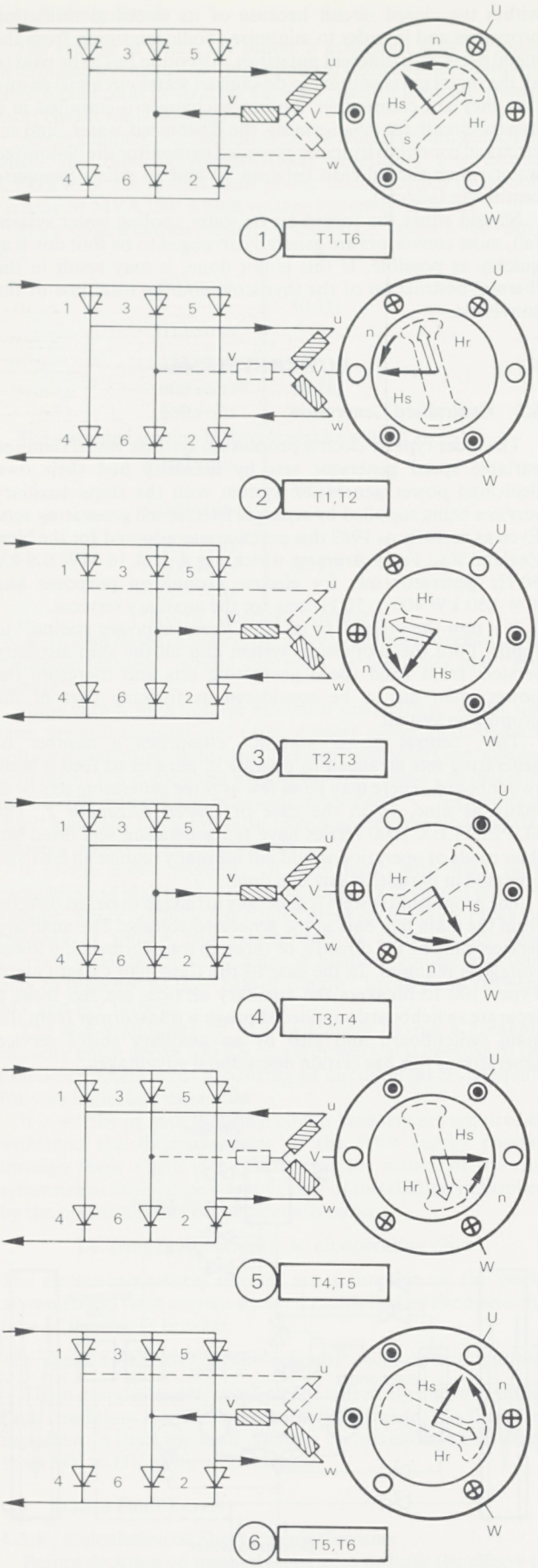


Figure 8 Synchronous Motor Powered by an Autosynchronous Inverter

to use a bank of capacitors. These are arranged to be charged during the conduction cycle of the bridge thyristors and when the bridge thyristors are required to be turned off the capacitors are switched so as to supply a reverse voltage to the thyristor anode thus commutating it.

An alternative method is to employ GTO's which can operate as on-off switches and replace the capacitors with electronic circuitry.

Both of the above methods require more electronics than an autosynchronous convertor of an equivalent size.

5.4 Reversal Manoeuvres

In common with other vessels, electrical propulsion is required to have sufficient power in reverse to bring the ship to rest from full ahead and also to go astern maintaining proper control of the vessel. This may be readily achieved in a.c. convertors by changing the sequencing of thyristor firing.

DC convertors may either be unidirectional, in which case changeover contactors are required, or reversible where the changeover is performed by thyristors connected back-to-back.

When making crash reversals, account has to be taken of the regenerative power that may feed back into the power system. For an FPP system, which is generally employed for ice-breakers, the motor has to be reversed and during the decelerating period to zero regenerative power is supplied. If this regenerative power is allowed to feed back into the power supply system it would have to be absorbed by the ship service load, generator prime movers etc., and it is therefore limited by the convertor controller to a value within the system's normal power absorbtion capacity.

To enable faster deceleration of the propeller dynamic braking resistors may be fitted.

Attention may have to be paid to the beginning of the manoeuvre to ensure that the unloading rate of the current controller of the convertor, which may be instantaneous, is suitably matched to the power reduction rate of the generator prime movers due to the governor/fuel rack/prime mover response. A mis-match could result in a transient prime mover overspeed which could be accommodated by a diesel engine but may trip a gas turbine, which has very little power absorption capacity.

5.5 Convertor Transformers

Convertors may be fed from the ship's system via transformers for several reasons:

(a) to effect a voltage change
(b) to obtain a phase difference between bridges and/or machine windings
(c) to reduce the effects of harmonics.

(a) Voltage Change
Propulsion drives can be designed to be compatible with the generated voltage. However there are many occasions when the generated voltage is either best transformed to a higher voltage, or to a lower voltage.

An example of the former are the CCG Type 1100 vessels where a standard 600 volt generated voltage was used and transformed to 1100 volts to supply the cycloconvertors. For d.c. propulsion motors, as used for the MICROPERI crane barge the generated voltage of 10 kV was transformed down to 660 volts to supply the rectifier bridge resulting in 740 V d.c. for the standard d.c. motors.

(b) Phase Difference
The new SITMAR cruise ship also transforms its generated voltage down from 6.6 kV to 3 kV to feed the motors and since they are 2 × 3 phase machines, the transformers are also used to obtain a 60 degree phase difference between the input supplies. This technique is

also used for the cycloconvertor where each leg of the bridge has to operate with a phase difference of 120 degrees.

(c) Reduction of Harmonics
Most convertors are 6-pulse which give rise to 5th, 7th and higher order harmonics. These harmonics can induce additional losses within electrical equipment giving rise to overheating. Reduction of the 5th and 7th order harmonics can be achieved by using a 12 pulse bridge, or alternatively, if two 6-pulse convertors are being used in synchronism they may be supplied through a common transformer, having a star and delta secondary, connected such that the convertors act as a 12-pulse unit.

For the cycloconvertor, which requires 3 × 3 phase supplies, a 67% improvement may be obtained whereas for a autosynchronous inverter requiring 2 × 3 phase supplies the 5th and 7th harmonics could theoretically be completely eliminated.

5.6 Thyristor Cooling

Heat is generated at the main semiconductor junction of the thyristor when it is conducting. Because of its small physical size, means have to be provided to rapidly remove this heat as failure to do so will result in the thermal destruction of the device.

Power thyristors are normally bolted or clamped to a heat sink whose purpose is to absorb the generated heat from the semiconductor junction. It is important therefore that good thermal contact is achieved between the thyristor and heat sink. The design of the thyristor ensures that the main semiconductor junction is electrically and thermally connected to one of the faces of the thyristor case in the "hockey puck" design, or the threaded stud in the device shown top centre in Fig. 4.

For very low power static convertors natural convection may be sufficient to cool the heat sinks and dissipate the heat from the semiconductor junctions. In such cases the heat sinks are of a finned aluminium construction, left natural or anodised black for more efficient heat dissipation. The shape ensures a high heat dissipation (i.e. watts/square metre) from the surface area within a small volume.

Most convertors, however, require some form of forced cooling in order to quickly dissipate the heat generated from the thyristor stacks.

The most common way of cooling is by forced ventilation either with the fan(s) fitted at the bottom of the cubicle, forcing the air up through the stack or with the fan(s) at the top drawing the air out. Consideration should be given by the manufacturer to providing two smaller fans rather than one large one for each cubicle so that in the event of a fan failure the convertor may be operated on reduced power. For convertors which have parallel legs of thyristors and a separate fan fitted for each leg, means should be provided to disconnect those legs for which ventilation is not available. Where there are alternative means provided, by system design, to maintain propulsion power, single fans may be accepted.

An alternative means of forced cooling thyristors is by using water which is passed through the heat sinks.

The cooling system (Fig. 9) generally comprises two circuits, a de-ionized closed water circuit, which passes through the heat sinks and dissipates the heat loss from the thyristors, and a raw water circuit which cools the de-ionized water in a heat exchanger. A single stage glandless centrifugal pump is used to circulate the de-ionized within a closed circuit. Changes in volume, caused by temperature differences in the circuit, are balanced out in an expansion tank with a nitrogen blanket. The nitrogen also prevents the de-ionized water in the tank from absorbing oxygen which cause corrosion in the closed circuit.

De-ionized water has a low electrical conductivity and is used within the closed circuit because of its electrical insulating properties and in order to minimise anodic migration from the metal parts with different polarities. Attention has to be paid to all the metal parts within the de-ionized water circuit to ensure that they are compatible. An ion exchanger is installed in a bypass circuit for regenerating the de-ionized water, and an electrical conductivity meter provided to monitor the de-ionized water which should read between 10 and 30 micro Siemens/centimetre (μS/cm).

Should either the forced air or water cooling water system fail, most convertors are generally arranged to be shut down as quickly as possible. If this is not done, it may result in the thermal destruction of the thyristors and the total loss of the convertor.

6. POWER SYSTEMS

6.1 Centralised Generation

The older type of electric propulsion systems which required variable speed generator sets by necessity had their own dedicated power generation system with the ships auxiliary services being supplied by separate fixed speed generating sets. Even as recently as 1983 this practice was adopted for the New Zealand Rail Ferry *Arahura* which has 4 × 4.16 MW 6.6 kV 50 Hz generator sets for electric propulsion purposes and 4 × 850 kW 400 V 50 Hz sets for the auxiliary services.

It is now the practice to install a "central power station" to supply both the propulsion system and all the ship auxiliary services from fixed speed generating sets and therefore the power plant has to be considered as forming part of the propulsion system.

The "central power station" comprises a number of generating sets arranged to operate in parallel to feed a main switchboard. There may be as few as three generating sets or as many as nine, as in the case of *Queen Elizabeth 2*. The SUPERFLEX 2000 ferries have ten generating sets fitted but their mode of operation would not normally require all ten to be operated in parallel at any one time.

The propulsion system is generally arranged to be fed directly from the main bus-bars at the generated voltage. The auxiliary services may be fed directly, or through transformers if a lower voltage is required. In the case of the Canadian Coast Guard Type 1100 Icebreakers the auxiliary services are fed from a separate switchboard supplied through a transformer from the main switchboard and also by an auxiliary ship's service generator as this has certain operational advantages.

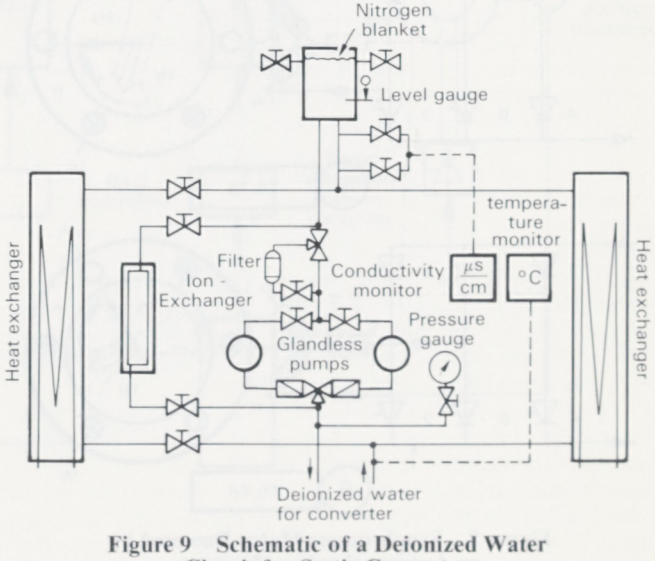


Figure 9 Schematic of a Deionized Water Circuit for Static Convertor

6.2 Voltage Levels

The voltage at which the power is generated is in the main determined by the size of the propulsion plant as this essentially governs the total generating capacity, and in turn the system short circuit fault currents.

Part 6, Chapter 2-1, Section 12 of the Rules recommends that where the capacity of individual generating sets exceed 2,500 kW or the system fault power under normal operation exceeds 50 MVA that a high voltage system be selected.

The standard marine medium voltages, i.e. below 1,000 volts, are:

380 volts 415 volts	50 Hz
440 volts 600 volts* 660 volts	60 Hz

The standard marine high voltages now used are:

3,300 volts 6,600 volts	50 Hz
4,160 volts* 6,000 volts 10,000 volts	60 Hz

(*North American Standard)

(N.B. In land based industry, the above voltages are regarded as "medium voltage" whilst 380 volts to 660 volts are "low voltage".)

Ships with a high voltage electrical installation, whilst not rare, are still unusual and often owners prefer that medium voltage installations be provided as ships' engineers are familiar with them. For companies with large fleets, crews can be easily transferred between all the vessels in the fleet. A "high voltage ship" generally has a specialist technical crew making transfer between vessels more troublesome.

It is the non-availability of switchgear with high fault capacities and high load currents which limits the use of medium voltage. There are very few circuit breakers having a breaking capacity of 100 kA rms symmetrical or above or for load currents in excess of 4,000 amps at medium voltage and this, may be regarded as the "rule of thumb" break-point between MV and HV systems.

The non-availability of MV switchgear having a breaking capacity much above 100 kA rms symmetrical is because of the practical limitations of producing air circuit breakers adequate for very high fault capacities.

It is worthy of note that such circuit breakers are required to withstand the thermal effects of the fault energy passing through them which is a function of the square of the rms symmetrical fault current at the point of installation multiplied by the operating time of the circuit breaker.

$$\text{i.e. (rms fault current)}^2 \times \text{cb operating time}$$

The electro-mechanical stresses are a function of the peak-asymmetrical fault current squared multiplied by the operating time of the circuit breaker.

$$\text{i.e. (peak asymmetrical fault current)}^2 \times \text{cb operating time}$$

These energies and stresses may be extremely high and under fault conditions could cause substantial damage. It is therefore expedient to limit the fault currents by increasing the voltage from MV to HV or by other means.

6.3 System Fault Levels

6.3.1 Calculation of Short Circuit Currents

Before deciding on methods to reduce or limit the effects of system fault currents the system prospective fault current levels must be calculated.

For installations having an installed generating capacity less than about 4 MW at 440 volts, the approximate values of fault contribution given in Pt. 6, Ch. 2-1, Section 3.3.5 of the Rules may be used provided allowance is made for the contribution from the propulsion motors. If these are of comparable ratings to the generators their contribution to the fault level should be taken as ten times full load current.

For high power installations a more accurate method of calculation is required, such as that given in IEC 363[6] or the method given by Morris and Klemm[7]. Both of these methods calculate the rms symmetrical fault current, peak asymmetrical fault current and/or system power factor under short circuit conditions. It is essential to know these values accurately when assessing the suitability of circuit breakers and contactor-fuse arrangements for high power systems similar to those of the *Queen Elizabeth 2*, the MICOPERI crane barge and the new SITMAR Cruise Ship.

6.3.2 Generator Reactances

It can be seen from the various methods of calculating short circuit currents that the single most important parameter is the "sub-transient reactance" of the generators. A low sub-transient reactance gives rise to high short circuit currents and vice versa. Designing the generators to have high sub-transient reactances would serve to reduce the system fault level.

There is however a penalty to pay in having high sub-transient reactance generators in that the generator transient voltage dip, when starting motors is made worse and if it is required to start large motors assisted start such as star-delta, may be required. The effect of the sub-transient reactance on the voltage dip has to be offset against the advantages in reducing the short circuit current and a compromise reached.

Most of the modern propulsion drives are "soft start" and do not normally give rise to high motor starting currents and therefore high sub-transient reactance machines may be used to advantage. This has been the case for *Queen Elizabeth 2* where the generators have a sub-transient reactance of 30.66% which at 10 kV allowed standard vacuum circuit breakers to be used with a conventional switchboard arrangement. If this figure had been lower, other measures would have had to be taken to reduce the fault level to within the capacity of available circuit breakers.

In the case of the CCG Type 1100 Icebreakers, the generators had a very low sub-transient reactance of 8% which combined with a medium voltage of 600 volts gave rise to a high system fault level of the order of 100 kA rms symmetrical. This necessitated one of the switchboard manufacturers having to back-up the main distribution circuit breakers with current limiting fuses as the fault level exceeded the capacity of their circuit breakers.

6.3.3 Back-up Fuses

The fitting of back-up fuses to limit the fault current seen by feeder circuit breakers is not unusual.

Back-up fuses are current limiting high rupturing capacity fuses which are fitted upstream of the feeder circuit breaker or contactor. Use is made of the fast operation of the fuse to rapidly cut-off the fault current before it reaches its first prospective peak. This limits the fault current seen by the circuit breaker or contactor and also the fault let through energy (I^2t) seen by the distribution system.

During plan approval the curves of the combined fuse and circuit breaker/contactor arrangement should be examined to ensure that it is satisfactory. Assurance may be required from the manufacturer that the circuit breaker or contactor is capable of withstanding the effects of the let-through energy (I^2t) of the fuse without damage.

Where back-up fuses have been used for propulsion motors as in the case of some of the CCG Type 1100 Icebreakers these have been very large, i.e. 6,000 amperes and their replacement could prove an expensive operation.

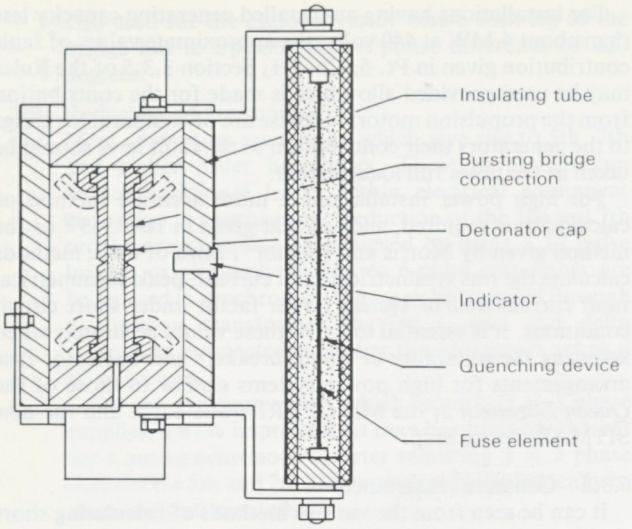


Figure 10 The Bursting Bridge Device

Back-up fuses may only be used for feeder circuits and therefore the main generator circuit breakers and main bus-bar system must be adequate for the full prospective fault level. For systems having very high fault levels it may prove necessary to limit the fault current by other methods.

6.3.4 Bus-section Fault Current Limiters

Short circuit current may be limited by automatically dividing the main bus-bars into two sections when a fault occurs, such that generators supplying the short circuit current are split between the sectionalized bus-bars. Each section of bus-bars, and the feeders from them, will see only a proportion of the total prospective fault current dependant upon the number of generators supplying that section.

For this arrangement to be effective, the bus-sectionalizing device must be rapid in operation so as to limit the short circuit current. It must also be required to carry the full load current of a number of generators without nuisance operation.

There are two devices which have been accepted as bus-section fault current limiters a bursting bridge device, and an extremely fast operating circuit breaker.

(a) The Bursting Bridge Device

The bursting bridge is a short hollow tubular conductor which forms the main current path (Fig. 10). It has four axial slots cut along it, has also been sawn through across the middle and the two halves resoldered together to form a breaking point. There is a detonator cap fitted inside the conductor at the soldered joint. The whole assembly is contained within an insulated pressure resistant shroud. Connected in parallel with the main current carrying conductor is a fuse type quenching device.

The unit is designed so that the main current conductor has a high current carrying capacity but a low short circuit current breaking capacity. The fuse type quenching device serves to break the high short circuit current.

The detonator cap, ignited by electronic tripping circuitry, causes the bursting bridge to open by deflecting the bars, formed by the four axial slots, towards the end faces of the unit. The current which was carried by the bursting bridge is diverted to the fuse type quenching unit which operates like an hrc fuse in interrupting and limiting the short circuit current. The whole operation may take only 0.6 milliseconds and because it is so rapid, the manufacturer carefully dimensions the fuse wire so that the interruption will only cause a small "switching" overvoltage.

The electronic tripping circuitry is normally arranged to be inoperative until the prospective short circuit current reaches a preset minimum. For example on a 6 generator installation the switchgear and bus-bars may be adequate for the short circuit current from 4 generators. Accordingly the bursting bridge would be arranged to be inoperative should any short circuits occur when up to 4 generators are connected in parallel. Any short circuits would be cleared by the normal protective devices. In the event of 5 or 6 generators being connected in parallel, the bursting bridge would operate, sectionalizing the bus-bars and limiting fault current at each section of bus-bars to a safe value within the short circuit capacity of the distribution protective devices. These would then operate to clear the fault.

To achieve rapid interruption of fault current, short circuits must be detected early and this is done by monitoring rate of rise of current (di/dt). A high rate of rise would indicate a severe short circuit.

(b) The Ultra Fast Circuit Breaker

This is a special circuit breaker designed specifically to limit very high short circuit currents. It comprises an electromechanical assembly which carries out the switching and an electronic control and monitoring sub-assembly forming the closing and tripping circuitry.

The opening and closing operations of the circuit breaker is achieved using the "Thomson effect" electrodynamic propellers. Each propeller comprises a fixed primary coil against which is held a solid disc which forms the secondary coil. A current passing through the primary coil develops a magnetic field which acts upon the eddy currents induced in the secondary coil which together form a "repulsion" magnetic circuit. The "Thomson effect" is proportional to di/dt and therefore the operating energy is electrostatically stored in capacitors which have the advantage that the stored energy may be released instantaneously and cause the necessary high rate of rise of current in the primary coil.

Upon detection of a minimum fault current by the control and monitoring circuits, the electrostatic energy is instantaneously released, by thyristor switching, into the primary coil. This results in a high induced current in the coil which, due to electrodynamic forces, rapidly repels the solid disc forming in the secondary coil. This operation may take place in less than 1 millisecond.

The kinetic energy of the solid disc is used to open the main contacts breaking the main current in about 2 milliseconds, auxiliary arcing contacts break the arc using arcing shutes, thus preventing excessive damage of the main contacts.

The circuit breaker is arranged to operate at a set short circuit current normally between 10–18 kA.

6.4 High Voltage Systems

6.4.1 General

Inevitably, the point is reached where it is impracticable and unwise to maintain the generating system at medium voltage and a high voltage system has to be employed.

A high voltage system also has the advantage that for high power in that currents are considerably reduced. This leads to smaller cross-section, and cheaper, cables, lower current circuit breakers/contactors etc.

On the other hand the creepage and clearance distances between live conductors and between live conductors and earth are increased. This means that HV switchboards are in general larger than an equivalent MV switchboard, which is particularly relevant for smaller vessels where space is at a premium.



Figure 11 QE2 10kV Main Switchboard

6.4.2 Creepage and Clearance Distances

For system voltages up to 6.6 kV minimum clearance distances are specified in Part 6, Chapter 2-1 Table 2.1.1 of the Rules from which it may be seen that in air the clearance distances are greatly increased for HV systems. Table 1 is a modification of that above, amended to cover voltages up to 10 kV and to take into account unearthed neutral systems.

Rated voltage (Volts) up to & including	Minimum Clearance (mm) between phases and earth		Minimum Clearance (mm) between phases
	earthed neutral	insulated neutral	
660	16	19	19
3,300	51	51	51
6,600	63	89	89
10,000	76	127	127

Table 1 Minimum Clearances

These clearances may be reduced by covering the bus-bars with a flame retardant insulating material. Reduced clearances must be proven by test using the full power-frequency high voltage test value as specified in Part 6, Chapter 2-1 Table 2.14.1 of the Rules for the appropriate voltage.

Creepage distances cannot be accurately specified as they depend upon the insulating material, dust deposits, humidity etc. As a guide for synthetic resin materials resistant to tracking and protected against dust and damp the values given in Table 2 may be used.

Rated voltage (Volts) up to & including	Minimum Creepage (mm) between phases and earth		Minimum Creepage (mm) between phases
	earthed neutral	insulated neutral	
660	25	38	38
3,300	51	76	76
6,600	89	124	124
10,000	127	190	190

Table 2 Creepage Distances

6.4.3 Switchboards

Apart from an HV switchboard being of a more massive construction (Fig. 11) there are other noteable differences from the MV switchboard.

One of the first things that may be noticed is that the board is divided into metal-enclosed compartments to contain any arcing effects. The circuit breakers/contactors, bus-bars, instrumentation voltage transformer and medium/low voltage circuits each generally having their own compartment.

The board may have pressure relief devices for the ejection of gases caused by arcing due to an internal fault. Provision of these is a matter for the switchboard builder and Owner, and account is to be taken of the relief devices and of the gases ejected in relation to the switchboard locations onboard the vessel.

The circuit breakers/contactors are generally mounted on withdrawable chassis. When withdrawn the main current carrying parts of the circuit breaker/contactors are automatically connected to earth, for reasons of safety, and shutters automatically close to cover the live fixed contacts.

If it is necessary to test the operation of the above devices, test facilities are generally provided within the switchboard. Because of the hazards involved, it is unsafe to test the devices whilst they are energised at high voltage.

In addition to the requirements in the Rules or IEC 92-503[8] the switchboards should comply with IEC 298[9].

High voltage circuit breakers should meet the requirements of IEC 56[10] and HV contactors IEC 470[11] or equivalent national standards. The HV fuses which may be required to back-up the contactors should comply with IEC 282[12] and, where the combined arrangement is for motor starting, IEC 632[13].

Reports of tests to show compliance with the above standards may be required to be submitted if considered necessary during plan approval. High voltage devices are given in the Society's Lists of Approved Type Tested Circuit Breakers and Fuses.

6.4.4 Current Interrupters

6.4.4.1 Air-break

At medium voltage most interrupters are of the air-break type but they are only used occasionally at high voltage. Some of the older 3.3 kV and 6.6 kV systems used air-break devices but they have been largely superseded by vacuum and SF6 devices.

The HV air-break interrupters operate in a similar manner to MV types in that the arc is broken in air. For contactors, fuses interrupt the large fault currents and the contactor only breaks small fault currents, otherwise the arc is broken in a similar manner as described below for the circuit breaker.

Arc interruption for the circuit breaker is achieved by drawing the arc into ceramic arc chutes in the top section of the circuit breaker. These chutes split the main arc into a series of shorter arcs which are then drawn into the refractory plates of the chute. This serves to considerably extend the arc and eventually extinguish it at a current zero, without overvoltages. The refractory plates, generally made of a zirconium silicate material having a high thermal inertia, also cool the arc and cause the arcing voltage to be distributed amongst them thus reducing the dielectric stress.

The arcing contacts are separate from the main current contacts and the circuit breaker has to be provided with arrangements to quickly drive the arc from the main contacts, to the arcing contacts and then into the chutes. This may be achieved by using the electromagnetic forces caused by the arcing current itself either directly or indirectly using magnetic blow-out coils.

6.4.4.2 Vacuum

These devices have been in industrial use for some 20 years. As the name suggests, the circuit current is interrupted by

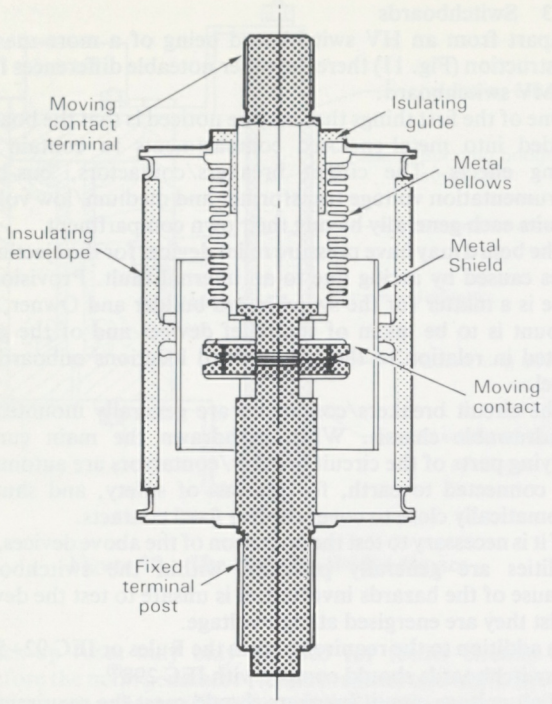


Figure 12 Vacuum Interrupter

contacts sealed in a vacuum envelope (Fig. 12). These interruptions take two main forms:

(a) a contactor type designed for frequent making and breaking motor starting and load currents
(b) a circuit breaker type designed to rupture fault currents a limited number of times.

The construction of the vacuum envelopes, or "bottles" as they are commonly known, is essentially the same. They may be made either from glass, ceramic or metal, though glass and metal are generally favoured as it is easier to join to the metallic end caps to make a good vacuum seal. Also with glass to some extent the condition of the contacts may be seen and a change in the glass from a silvery mirror like finish to a milky white colour would denote that the bottle is losing its vacuum and should be replaced.

The bottles are evacuated to a vacum of 10^{-7} torr (mm of mercury) and sealed. On the basis of extensive tests the manufacturers guarantee the bottles have a shelf life of 20 years, which means they may be stored for 20 years after which time they will still perform as could be expected from a new device.

As touching metals held in a vacuum tend to weld, suitable contact materials must be selected which are soft enough to be broken when the interrupter is required to be opened and yet cope with the electrical performances required. This is a complex problem on which much research has been carried out. The type of contact materials used determines whether the device is for contactor or circuit breaker use.

As vacuum contactors are not designed to switch fault currents for distribution circuit use, they must be provided with short circuit protection. It is generally recommended by the manufacturers that fuses be used wherever possible as they have a current limiting effect. The contactor/fuse combination is to be so arranged that under short circuit conditions the fuse limits the I^2t let-through energy to a value not exceeding the I^2t withstand capability of the contactor. This may be established by performance test data. Only overload currents should be broken by the contactor.

The circuit breaker is designed to switch fault currents and when the contacts separate the current to be interrupted initiates a metal vapour arc from the last point of contact. The fault current continues flowing through this plasma. In order to prevent local erosion and excessive heating at the arc roots the contacts are specially shaped to prevent the arc remaining stationary, in fact its own magnetic field causes it to rotate around the external edges to the contacts. As the arcing current approaches its natural zero, there is insufficient energy to maintain the plasma and therefore the arc is not supported and is extinguished. Within a few microseconds the vacuum chamber and the contacts have re-established their original condition.

In order to maintain the metal vapour arc discharge, a certain minimum current must flow. If the current is below this minimum level it is "chopped" before it reaches a current zero which can give rise to high overvoltage spikes when switching inductive circuits such as motors. The vacuum circuit breaker manufacturers endeavour to limit this current chopping when designing their devices.

The overvoltage spikes could cause premature breakdown of cable and machine insulation. For new installations, modern insulants can be selected to withstand the effects of such spikes or voltage surge diverters may be fitted in the switchboard in order to limit the spikes to a harmless level.

Both *Queen Elizabeth 2* and the MICOPERI crane barge have vacuum interrupters fitted in their 10 kV switchboards with suitable measures taken to limit the adverse affects of any switching overvoltage spikes. *Queen Elizabeth 2* has an existing 3.3 kV distribution system and to have used vacuum interrupters in this new switchboard may have led to breakdown of the insulation of the existing cables and 3.3 kV machines which are some 25 years old. The Owners therefore decided to install SF6 interrupters.

6.4.4.3 Sulphur Hexafluoride (SF6)

These devices also have been in use for some 20 years primarily in the electrical supply industry for voltages up to 800 kV as replacements for air-blast circuit breakers. In more recent years they have been further developed as sealed units and have decreased in size and voltage making them suitable for marine applications. In common with the vacuum interrupters these devices take two main forms, that of the contactor type and of the circuit breaker type.

SF6 is a non-flammable and non-toxic gas having remarkable thermal and electrical properties making it a good medium for current interruption.

For each pole, the contacts are sealed in an enclosure of epoxy-resin or similar material, containing the SF6 gas at a nominal low pressure of 1.5 to 2.5 bars. The sealed units have a guarantee similar to that for vacuum bottles.

Unlike the vacuum interrupters which have only one set of contacts per phase, the SF6 devices have separate main current breaking contacts and arcing contacts.

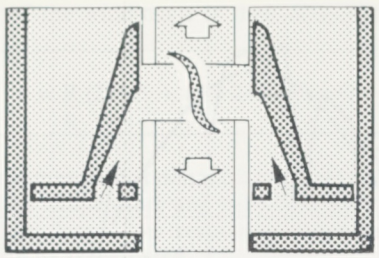
Two methods are used to cool and break the arc due to the short circuit current:

(a) the puffer technique
(b) the rotating arc technique.

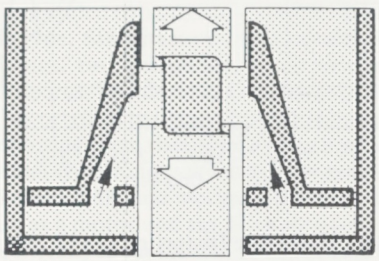
(a) Puffer Technique

When the arcing contacts open, they drive a piston which compresses the SF6 gas (Fig. 13a). This compressed gas is directed by an insulated nozzle to between the arcing contacts. The arcing contacts are of a hollow tubular construction and the SF6 gas passes around them across the contact faces evacuating the hot arc gasses through their interior by forced convection.

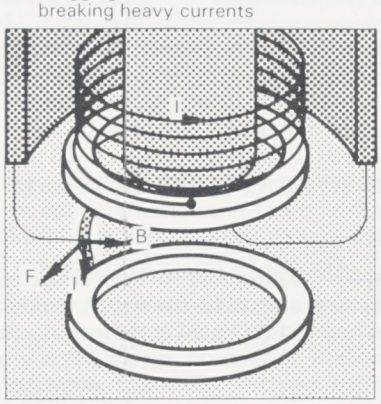
This technique is effective over a wide range of load and fault currents. Under heavy current breaking conditions the arc occupies the whole of the space between the arcing contacts. This is a natural phenomenon and is known as the "clogging" effect (Fig.



a) Puffer technique:
breaking low currents



b) Clogging Effect:
breaking heavy currents



c) Rotating Arc Technique

Figure 13 SF6 Interrupters

13b). The arc energy under these conditions is limited by the opening extent of the arcing contacts which limits the length of the arc. As the gas flow is impeded by the arc almost all of the gas within the enclosure is compressed by the piston. When the current passes through its zero and the arc extinguishes, the compressed gas passes across the contact faces effectively evacuating the hot arc gases.

Excessive wear of the arcing contact surfaces is prevented as the roots of the arc are from the interior of the hollow arcing contacts.

(b) Rotating Arc Technique

To remove the heat produced by the electric arc relative movement must be created between it and the SF6 gas. In the rotating arc device this is achieved, as the name suggests, by causing the arc to rotate (Fig. 13c).

In order to rotate the arc the arc current itself is passed through a solenoid coil which sets up an intense electromagnetic field around the fixed circular arcing contact and in parallel with it. When the circuit breaker opens an arc appears between the fixed and moving arcing contacts, resulting in a conductive plasma through which the arcing current flows. This current is perpendicular to the magnetic field and the effect of this combination causes the arc to be accelerated into a rotating motion because of the "Laplace" force exerted upon it.

The solenoid is designed such that the rotational speed of the arc is extremely high during the arcing period.

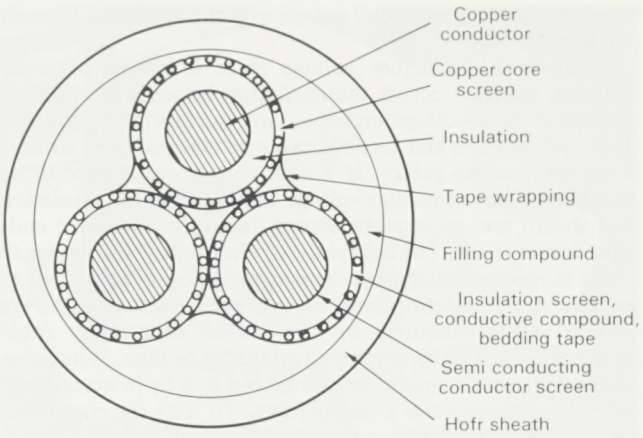


Figure 14 Typical High Voltage Cable Construction

The higher the fault current, the faster the arc will rotate and be effectively cooled by the SF6 gas. The electromagnetic forces applied to the arc to move and cool it are proportional to the curent to be broken. As the arcing current approaches its zero its value decreases and also the magnetic field, the decaying arc loses speed and is eventually extinguished. This occurs after the current zero in order to help prevent the arc restriking. After the arc is extinguished SF6 gas passes between the contacts to serve as an insulant against the recovery voltage and the arc restriking.

In common with the vacuum interrupter, excessive wear of the arcing contacts is minimised by the continuous movement of the arc roots.

6.4.5 Voltage Surge Diverters

Voltage surge diverters or arresters are devices that are used to protect equipment against voltage surges of a transient nature such as caused by switching. They are generally installed in the high voltage switchboard connected directly between the bus-bars (line) and earth. By conducting the energy of the voltage surge to earth, they limit it to a safe value.

There are two types that have been used on marine systems, one incorporating a spark gap with non-linear resistances and another employing extreme non-linear resistances, but for the purposes of a simple explanation of their operation they may be regarded as similar.

At its rated service voltage, which would normally be ship's nominal generated voltage, or slightly higher, the diverter exhibits high-ohmic characteristics and passes only capacitive leakage current to earth. At higher voltages, it immediately exhibits low-ohmic characteristics and discharges high current surges to earth. As soon as the voltage reduces to the rated service voltage the arrester again assumes high ohmic characteristics.

These devices should meet the recommendations of IEC 99[14] or an equivalent national standard.

6.4.6 High Voltage Cables

The construction of high voltage cables may differ to that of medium voltage cables in that semi-conducting tapes or compounds may be incorporated as shown in Fig. 14.

As the result of the voltage on the conductors there is a high dielectric stress set up between these and the insulation. In the event of there being air voids at this interface these may break down and the ozone created attack the insulation and cause cable failure. In order to prevent this and to equalise the electric stresses over the internal area of the cable insulation a semi-conducting compound or tape is applied over the conductor. Some constructional standards also require a

semi-conducting compound or tape over the insulation beneath the sheath.

Because of the higher voltage there is also a potential (voltage) gradient across the insulation between the internal surface at high voltage and the outer surface at a potential approaching earth and account has to be taken of these stresses when terminating cables. If a high voltage cable were to be terminated like a medium voltage cable, where the insulation and sheath are cut straight across, failure at the cable ends would soon result. The behaviour of electric stress is similar to stress in mechanical systems in which corners are rounded to equalise stress concentrations. Electric stress concentrations are avoided at terminations by the use of proprietory cable termination kits or by stress control tubing or tape. Whichever method is used, it should be carried out strictly in accordance with the manufacturer's instructions. To tests the completed termination, a test voltage in accordance with IEC 502[15] may be applied.

6.5 Electromagnetic Interference

6.5.1 Radio Frequency Interference

The thyristors within the convertors carry out their switching operations at high speeds, with almost "step" changes in the voltages being switched. These very high switching rates give rise to high frequency components and therefore static convertors are a known source of radio frequency interference (RFI).

RFI may be conducted or induced into circuits causing problems to other equipment and measures have to be taken to prevent this.

Conductive coupling of high frequency interference may be contained within the primary generating system and not transmitted to sensitive equipment supplied at a secondary voltage, by fitting an earthed screen between the transformer windings.

Inductive coupling occurs when the cables carrying the high frequency interference are run in close proximity to other cables which are then polluted. Provided the 'dirty' cables are identified and are segregated from the 'clean' cables, then there should be no problem. Guidance on installation practice is given in IEC 533[16].

6.5.2 Harmonic Distortion

In a conventional thyristor bridge which relies upon cyclic switching of the thyristors to give a controlled output, the current drawn from the supply comprises a component at the supply frequency, i.e. fundamental frequency, with a number of harmonic currents. The harmonic components of the input current are of order $(np \pm 1) \times$ supply frequency, where n is an integer 1, 2, 3 etc., and p is the pulse number of the convertor.

A 6-pulse convertor will produce 5th, 7th, 11th, etc., harmonics and a 12-pulse 11th, 13th, 23rd, 25th, etc., each which will distort the system voltage. The lower harmonic voltages have greater magnitudes and therefore may be more of a problem. A 6-pulse convertor may be arranged so as to reduce or eliminate the lower harmonics, i.e. 5th and 7th, as detailed in section 5.5.

A typical distorted waveform is shown in Fig. 15 which could cause additional temperature rises due to frequency dependant losses in equipment such as machines, transformers, coils, capacitors etc. For equipment suppliers to accommodate such voltage distortions, the total harmonic voltage distortion for the convertor voltage output waveform has to be calculated and this may be carried out using Fourier analysis. All the convertors fitted must be considered in the analysis.

If the total voltage distortion proves unacceptable for the equipment to be installed, harmonic filters may be fitted to the convertors to reduce the offending frequencies to an acceptable level. Part 7 Chapter 4 Section 3.5.1(b) of the Rules specifies

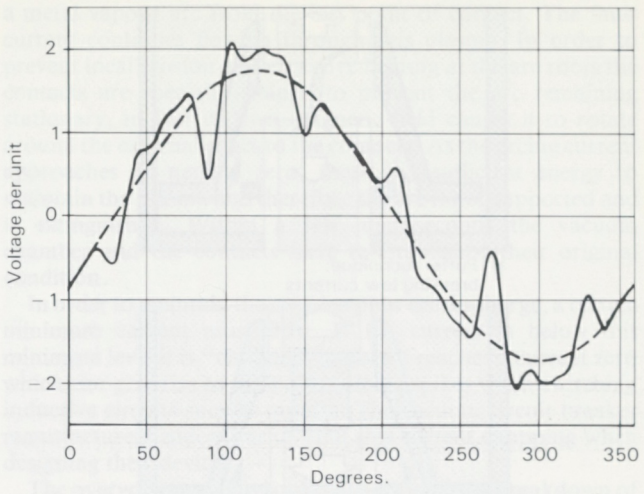


Figure 15 Harmonic Distortion (up to 25th order)

requirements for dynamic positioning electric propulsion systems fitted with static convertors.

7. SURVEY AT MANUFACTURERS

7.1 General

Part 6, Chapter 2-2, Section 13 of the Rules requires the main electrical equipment and cables for electric propulsion systems to be surveyed and witness tested at the manufacturer's works.

For the modern propulsion system, this would include generators, main switchboard, static convertors and their transformers (if fitted), propulsion motors and main cabling.

It is not intended to detail survey or testing procedures as these are laid down in the Rules and standards. Guidance is also given in LRTA papers by Morris[17] and de Jong[18].

The following sub-sections illustrate some differences that may be encountered for modern propulsion systems.

It should be noted that for some system designs, such as the cycloconvertor, it may only be possible to carry out the tests on a completed system as each part of the system is interdependant. If each of the main components are built by different manufacturers, or at different works, some "manufacturers" tests can only be carried out on-board. In such cases, the builders are to be made aware of the outstanding tests so that adequate time may be allocated during the vessel's trials programme.

7.2 Machines

7.2.1 Rule Requirements

Part 6 Chapter 2-1, Section 4.11 of the Rules details the tests to be carried out and Section 14.3 the additional requirements applicable to high voltage machines.

7.2.2 Temperature Rise Tests

Those who have witnessed machine testing are familiar with the procedures adopted at medium voltage where the machines are subjected to a temperature rise test by continuous loading. To obtain the temperature rise of the machine as per Part 6, Chapter 2-1, Table 24.1, the resistance R_o is measured when the machine is cold, i.e. at ambient temperature t°deg.C. The machine is loaded to full load current and run until it reaches a steady temperature with inlet and outlet air temperatures measured by thermometers. After the machine is shut-down, the stator winding resistance R is measured and the average

temperature of the windings t is then determined from the formulae:

$$t = \frac{R}{R_o}(234.5 + t_o) - 234.5 \text{ deg.C.}$$

A small error in measuring resistances may make a large error in determining the temperature and therefore this method is not always used for large, low resistance, machines where the problem would be exacerbated.

In larger machines the stator winding temperature may be measured by embedded temperature detectors of a resistance or thermocouple type. Six detectors are normally built into the machine windings, two per phase, for in service monitoring purposes with spares. The detectors measure total temperature which has to be corrected to obtain the temperature rise. For the purpose of reporting these rises may be averaged out.

If two identical synchronous machines are available they may be connected electrically and mechanically back-to-back. One machine is run as a motor and the other as a generator with its output fed electrically to the motor. The losses are supplied by a third machine connected to the main electrical supply of the factory. In this back-to-back, or synchronous feedback test, either machine may be under test and it should be noted that one machine will be operating with reverse rotation, unless the machines are handed. If the machines have an integral shaft cooling fan it would be running backwards and, therefore, an auxiliary cooling fan should be fitted for the purpose of the test. The temperature rises should be measured only on the machine operating in the correct rotation using its own fan for cooling.

If the machines prove too large to continuous load them, separate heat run tests may be carried out with:

(a) rated voltage and terminals open-circuited

(b) rated rotor current with terminals short-circuited

(c) zero excitation.

From these tests the temperature rises may be computed. IEEE Standard 115[19] details the appropriate methods. For asynchronous machines IEEE Standard 112[20] should be used.

To obtain the synchronous machine rotor temperature rise, the resistance method may be used. The above standards detail adaptations of this method should the rotor take a long time to stop.

7.2.3 High Voltage Tests

The coil tests and voltages specified in Part 6, Chapter 2-1, Section 14.3.2 are based on the machine's insulation level is at its final value during construction, as would be the case for these wound in the traditional manner. There are, however, modern insulants that do not achieve their final insulation level until after all the wound coils are installed and the completed rotor or stator is subjected to a further process which encapsulates the complete winding. Major manufacturers who are known to be using such insulants have had their test procedures reviewed in Headquarters and equivalence to the Rule requirements agreed.

7.3 Main Switchboard

The majority of main switchboards for non-electric propulsion vessels are witness tested at the manufacturer's works although it is not a specific Rule requirement. Most manufacturers, therefore, would have an agreed established test procedure.

It would be expected such tests incorporate functional tests, high voltage withstand and insulation resistance tests and, if current injection equipment is available, selective calibration checks on the generator and propulsion motor circuit breaker overload and short circuit tripping devices/relays. Thereafter the relays should be sealed or marked to indicate the final settings.

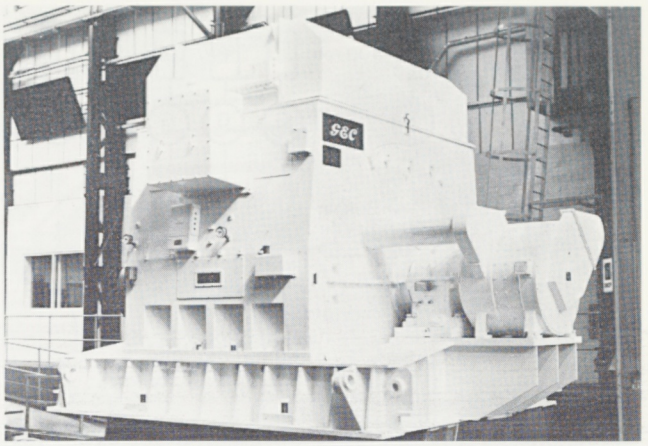


Figure 16 QE2 Main Generator

In addition to witness testing, the switchboard is to be surveyed during construction to approved plans. Particular attention should be paid to the short circuit bracing arrangements, clearances between bus-bars and bus-bars and earth and cable/wire terminations.

7.4 Static Convertors

These are to be surveyed during construction to approved plans, with attention paid to the securing arrangements of the printed circuit boards and the clearance distances between current carrying parts and earth.

Where it is possible to carry out tests at the manufacturers works on the convertor, it would be expected such tests include an open circuit test at rated voltage, a nominal short circuit test at rated current, checking the balance between phases and a functional test on the alarm control and monitoring circuits. It may also be demonstrated that the convertor is able to drive a test motor up to rated speed.

7.5 Cables

These are to be surveyed and witness tested to establish compliance with an appropriate national or international standard. For medium voltage cables IEC 92-351[21] may be used and for high voltage cables IEC 502[15].

8. SOME NOTEWORTHY SYSTEMS

8.1 Queen Elizabeth 2

8.1.1 The Re-engining

The re-engining of the passenger vessel *Queen Elizabeth 2* was undoubtedly the largest maritime project of its kind ever undertaken. When the vessel was built in 1969 it was powered by three boilers and steam turbines driving two 5.8 metre fixed pitch propellers. The maximum output was of the order of 60 MW with a ship speed of 28.5 knots. The installation was fuel hungry and had a chequered history of problems.

In Lloydwerft Shipyard, Bremerhaven the steam propulsion machinery, boilers, generators and propellers were removed and replaced by a diesel-electric installation driving two 5.8 metre controllable pitch propellers each having a Grim vane wheel of 6.7 metre diameter.

8.1.2 Central Power Station

A central power station was installed comprising 9 a.c. generators each rated 10.5 MW 10 kV 60 Hz (Fig. 16) and driven by an M.A.N-B&W. 9-cylinder 9L58/64 four-stroke diesel engine of rating 10.62 MW at 400 rev/min.

The generators were manufactured by GEC Turbine Genera-

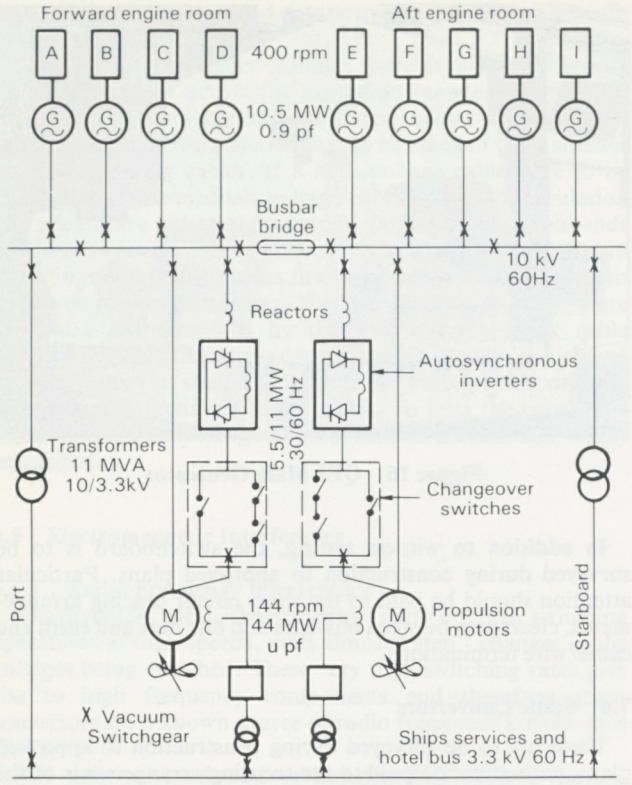


Figure 17 QE2 Power System – Simplified Diagram

tors at Stafford, England under special survey and are two bearing, salient pole, three phase synchronous machines. The generators are rigidly mounted to the ships structure whilst the engines are resilient mounted to meet the Owner's requirement "that the noise and vibration levels were not to exceed those of the existing steam propulsion plant." The generators are driven by the engines through Vulcan-Rato flexible couplings.

The generators have Class F insulation with Class B temperature rises, as specified by the Owners. Heat run tests were carried out on the machines using the zero factor method and measuring the stator temperatures by thermocouples. The rotor and exciter temperature rises were computed from measurements of voltage and current.

As the generators have a totally enclosed air circuit which is water cooled via a heat exchanger they are classed as water-cooled machines in terms of Part 6, Chapter 2-1 Table 24.1 of the Rules. The engines, generators and bearings are designed for a common cooling water supply at an ambient temperature of 38°C. The bearings are also designed for the same lubricating oil as the engines.

Five generator sets are installed in the aft engine room and four in the forward with all their services arranged so that any one fault in an engine room will not affect the other. The generator sets are arranged for unattended operation in compliance with Part 6, Chapter 1, Section 3.2 with a GEC "GEM80" microprocessor surveillance system.

8.1.3 Main Switchboard

The generators feed a 10 kV main switchboard (Fig. 11) through vacuum circuit breakers. The 23 cubicle switchboard is arranged to be split into at least two independent sections with one section, 8.2 metres long, fed by the five generators in the aft engine room and the other section, 7.3 metres long, fed by the generators in the forward engine room. The services fed from the switchboard are equally distributed between these two independent sections which are in separate compartments and connected together through vacuum bus-tie circuit breakers by a bus-bar bridge (Fig. 17).

Further sub-division of the switchboard is possible using wing bus-tie circuit breakers which at the recommendation of the author have been provided to isolate three generators to supply only the ship's service transformers. For normal operation all the bus-tie circuit breakers are closed and the system operates as a solid bus-bar. In the event of extremely heavy weather when the propulsion motors may present a fluctuating load to the generators, causing an unacceptable frequency and voltage fluctuation for the ship's hotel and auxiliary services, these wing circuit breakers may be opened.

The 10 kV switchboard is rated for the system fault level of 40 kA rms symmetrical, 103 kA peak asymmetrical. It has complete segregation between LV and HV services. The 10 kV distribution system has an insulated neutral which necessitated enhanced clearance and creepage distances between phases and between phases and earth. Also since transient-overvoltages due to switching are considered to be greater with an insulated neutral system, surge diverters were fitted in order to reduce their deleterious effects.

8.1.4 Service Transformers

Apart from the electric propulsion there are only two other outgoing feeders, those for the two ship service transformers. These transformers are each rated at 11 MVA, so that either can supply the total hotel and auxiliary loads giving 100% redundancy. The transformers are cooled by a synthetic transformer fluid called "MIDEL" which is non-flammable and a non-pollutant.

8.1.5 Static Convertors

The port and starboard electric propulsion systems each have two feeders, one to supply the static convertor and one a direct feed to the motor.

The static convertors are of a 6-pulse autosynchronous inverter type, manufactured by GEC Industrial Controls under their trade name "SYNCDRIVE". They each have a maximum rated output of 11 MW at 60 Hz. The primary purpose of the convertors is to start the propulsion motors. With the CPP set at zero pitch the motors can be started and run up to 72 rev/min. At this motor speed 5.5 MW of power is available for propulsive power from each of the convertors. The convertors have therefore a secondary purpose for low speed manoeuvring and cruising. By means of a combinator control the pitch of the propellors can be set in conjunction with the speed of the motors, as indicated in Fig. 18, up to a maximum power of 11 MW per motor at 144 rev/min.

For powers above 11 MW the motors are synchrophased with each other and synchronised onto the main bus-bars, and

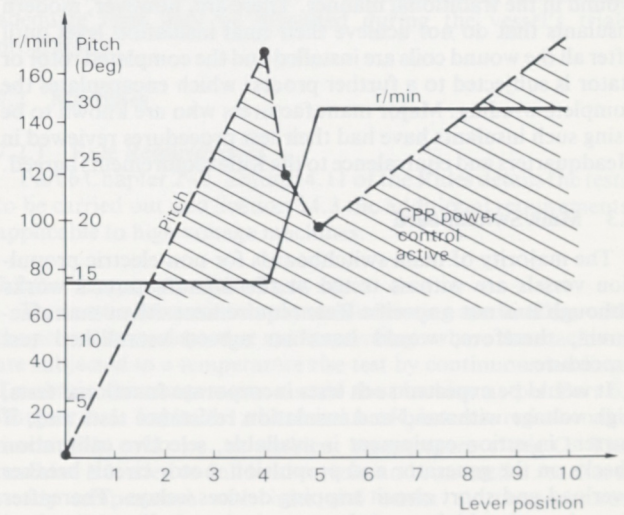


Figure 18 QE2 Combinator Control (Fwd)

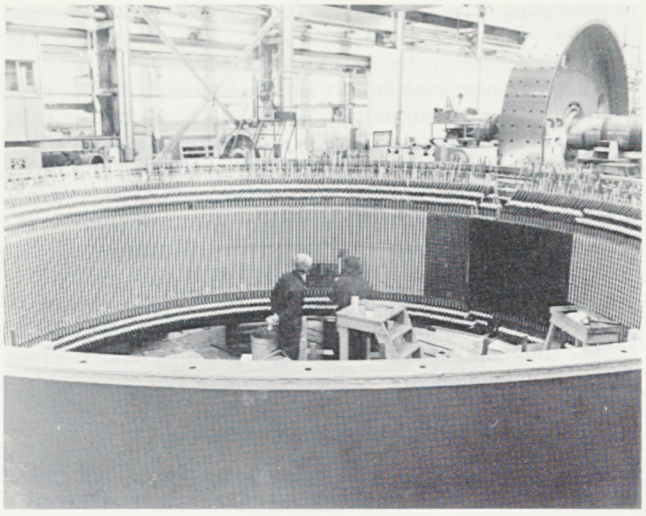


Figure 19 QE2 Winding Propulsion Motor Stator

thence operated at 144 rev/min with the pitch of the CPP then being adjusted to change propulsive power.

Arrangements are fitted so that if a convertor were lost the remaining one could be used to sequentially start both motors. Under these conditions from zero to full power would be controlled by the CPP. As there was this redundancy in the system the convertor was not required to be capable of operating at a reduced power as detailed by IEC 92-501.

Vacuum circuit breakers are fitted on the output side of the convertors to protect against the effects of the fault current supplied by the propulsion motor in the event of an internal fault in the convertor whilst it is powering the motor. These circuit breakers would be expected to operate at below their normal rated frequency and the manufacturer showed by test data and theoretical calculation that the performance of the circuit breakers was unaffected by these reduced frequencies.

If a propulsion motor were to be inadvertently tripped it may be reconnected to the system by taking the pitch off the propeller to reduce the motor demand to below 11 MW and the connecting the motor onto the convertor. As the convertor is machine commutated it will automatically assume the speed of the motor and therefore the motor may be re-established to its previous operating condition.

8.1.6 Propulsion Motors

The propulsion motors are 50 pole synchronous machines rated at 44 MW at 144 rev/min 10 KV 60 Hz and are the largest motors ever supplied for a marine propulsion plant and may even be the largest built (there are however larger generators of a similar construction).

The machines were manufactured by GEC Large Machines at Rugby under special survey and Figs. 19, 20 and 21 show them under construction. The man in the cradle is measuring the air gap between rotor and stator.

The motors are 9 metres wide, 8.45 metre high, 5.7 metres between coupling faces and weigh 285 tonnes each. For transportation purposes the motors were disassembled into component parts and reassembled at the shipyard before being installed on the vessel as complete motors.

In common with the generators the motors are "totally" enclosed water cooled having Class F insulation and Owner specified Class B temperature rises. The cooling air is circulated through the motors and heat exchangers by auxiliary electric fans. There are 4 heat exchangers with 2 fans on each motor which dissipate some 130 kW of heat at full power.

Totally is put in parenthesis above as there is an air outlet

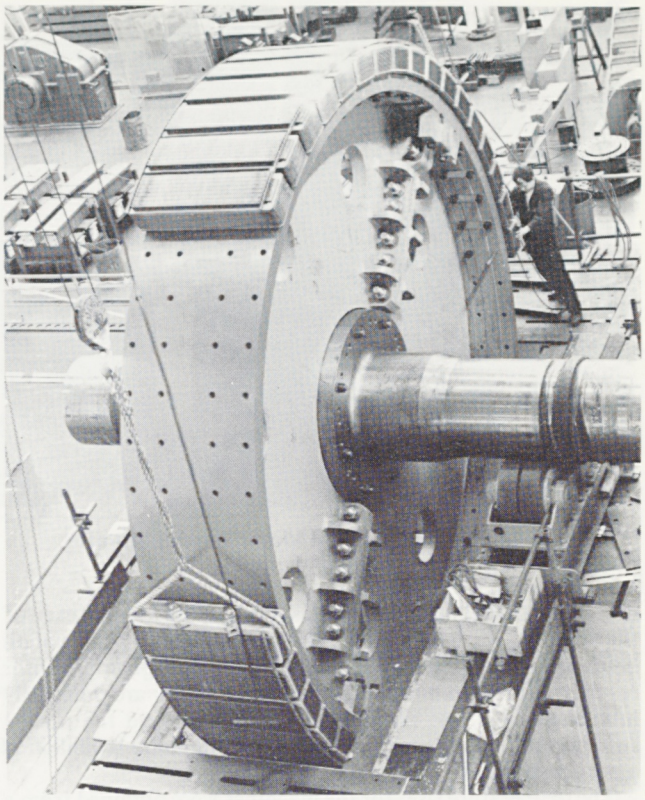


Figure 20 QE2 Assembling Propulsion Motor Rotor

aperture and make-up air inlet. The motors have static exciters, one for each machine and one spare, and in order to supply excitation current to the rotors, slip rings and carbon brushes are provided. Such arrangements would lead to the build up of carbon dust within the machine windings. To prevent this the slip rings and brushes are contained in their own compartment within the main housing of the motor. A small quantity of air is vented through this brush compartment from the motor room via a filter.

In compliance with Part 6, Chapter 2-1, Section 1.2.8 of the Rules, the motors are watertight to just below the shaft line and to test the efficacy of the proposed sealing arrangements the motor casings were filled with water before assembling the stator windings.

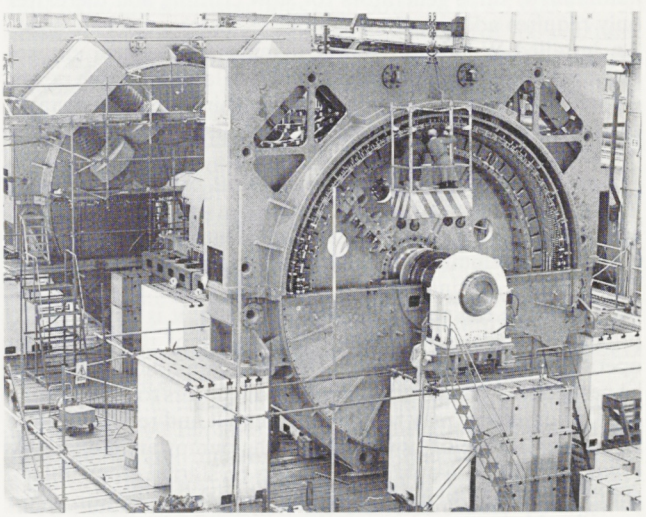


Figure 21 QE2 Propulsion Motors assembled for test

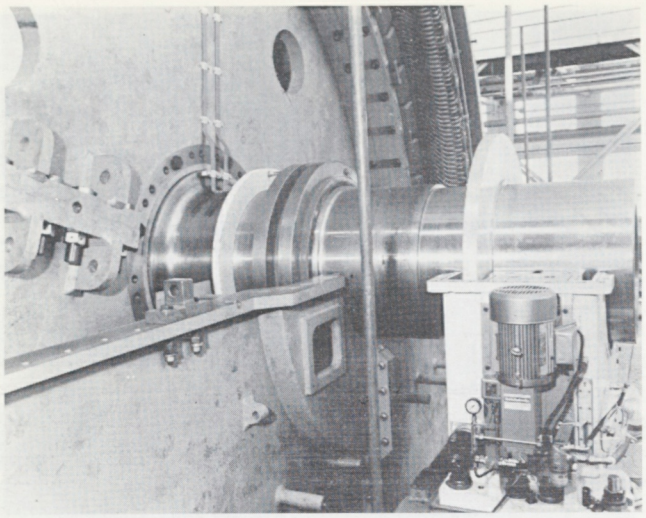


Figure 22 QE2 Propulsion Motor Bearing showing jacking oil pump

High pressure oil jacking pumps (Fig. 22) are fitted to each of the two bearings so that as the shaft may be lifted by a film of oil before the rotor is turned and the motor started. Once the motor reaches a predetermined speed the bearings are integrally lubricated by a disc and wiper arrangement and the pumps switched off. Upon speed reduction the pumps also switch on at a pre-set speed.

The temperature rises for the machines were obtained from a computation of the results obtained from no field, open circuit and short circuit heat run tests. One motor was subjected to a sudden short circuit test at 50% and 75% rated output voltage (whilst the motor was being driven as a generator) to demonstrate the ability of the machine to withstand shock loading and also to verify some of the machine design parameters.

8.1.7 Repairs and Maintenance

Because of the difficulty of removing the motors and generators after installation they are designed such that repairs may be carried out in situ. Such repairs would be undertaken by specialists from the manufacturer and not by ship's staff.

8.1.8 Operation

The diesel-electric propulsion system should prove reliable and flexible in operation and offer a considerable fuel saving over the steam turbine plant. The vessel may operate with a minimum of three generators for slow cruising and thereafter only requires additional generators to match power demand. An installed Woodward power management system ensures sufficient generators are running and available to match power demand. As a passenger liner/cruise ship has a predictable pattern of operation a power management programme may readily be specified.

Apart from normal operation, account had to be taken of various failure modes such as the loss of a generator, or of one engine room and appropriate safeguards built into the system to ensure the continuing safety of the vessel, passengers and crew.

For vessels having very large generator sets where all the pumps on the engine are electrically driven, it is important to provide arrangements to keep at least one of the generators operating under all conditions. Under certain conditions it may be necessary to trip the main propulsion motors to achieve this, as to do otherwise may result in a blackout and resource to the emergency source of power. As all the pumps are electrically driven, the vessel would then have to be started from "black ship" conditions which could take some time and also cause considerable inconvenience to the passengers.

When the propulsion system is in combinator mode, any loss of generating capacity available for propulsion causes a rapid reaction within the static convertor thus preventing the remaining generators from being overloaded.

When the propulsion motors are synchronised onto the main bus-bars change of propulsion power can be effected only by pitch control. Under these conditions if there is a sudden loss of a generating unit there may well be insufficient generating capacity remaining for the propulsion demand and it may not be possible for the power management system to reduce the propeller pitch fast enough to prevent system frequency collapse and blackout. Provision has therefore been made to trip the circuit breakers of the propulsion motors should the generators be subjected to a sustained overload in excess of 105%, thus ensuring the supplies to lighting and essential pumps are maintained.

8.2 The SITMAR Passenger Cruise Vessels

Unlike the *Queen Elizabeth 2*, which frequently undertakes transatlantic crossings, cruise ships generally ply their trade in a more leisurely manner and therefore do not require the enormous power for fast passage.

The new SITMAR cruise vessels are propelled by 2 × 12 MW synchronous motors driving fixed pitch propellers. The central power stations comprise 4 × 9.4 MW 6.6 kV 60 Hz generators driven by M.A.N.-B&W 6L58/64 diesel engines. The propulsion systems have a number of interesting noteworthy features which differ from the *Queen Elizabeth 2* installation.

A 6.6 kV high impedance earthed neutral generation and primary distribution system has been chosen along with air-break circuit breakers in order to minimise switching transient-overvoltages. Filters are also fitted across the bus-bars feeding the static convertors to reduce the effects of harmonic distortion.

Again, for simplicity, static convertors of the 6-pulse auto-synchronous type are fitted but connected as 12-pulse units to eliminate 5th and 7th order harmonics. The convertors are arranged to continuously feed the propulsion motors and this is the only method propulsive power may be changed. The output frequency is limited to 39 Hz.

The two propulsion motors are 24 pole synchronous machines having two sets of 3-phase windings with a combined maximum output of 12 MW at 3 kV 39 Hz 145 rev/min. Each motor may be operated as a 6-phase machine, supplied by two convertors operating in a 12-pulse mode, or as a 3-phase machine at half power supplied by one of the convertors operating in a 6-pulse mode. As the power/speed curve is a cubic function half power gives a reduced maximum speed of 120 rev/min.

8.3 The Carnival Cruise Line Vessel

This vessel may indicate future trends in convertor systems in that a cycloconvertor system is being proposed, as against the autosynchronous inverter used for the previous passenger vessels. At the time of writing only vague details are available but it is suggested, based upon the shipbuilder's experience with icebreakers, the convertor will employ GTO's making the cycloconvertor an attractive proposition.

From the information at present to hand the central power station will comprise 4 × 8.8 MW and 2 × 5.84 MW 6.6 kV 60 Hz diesel driven generators, with two propulsion motors each rated at 14 MW.

8.4 The "SUPERFLEX 2000" Ferries

These small Ro-Ro passenger-vehicle ferries (Fig. 23) are designed for sheltered inter-island trade where the journey times are short. They can operate a shuttle service and have the facility of propulsion both ends.

It is how the propulsion system is arranged in conjunction

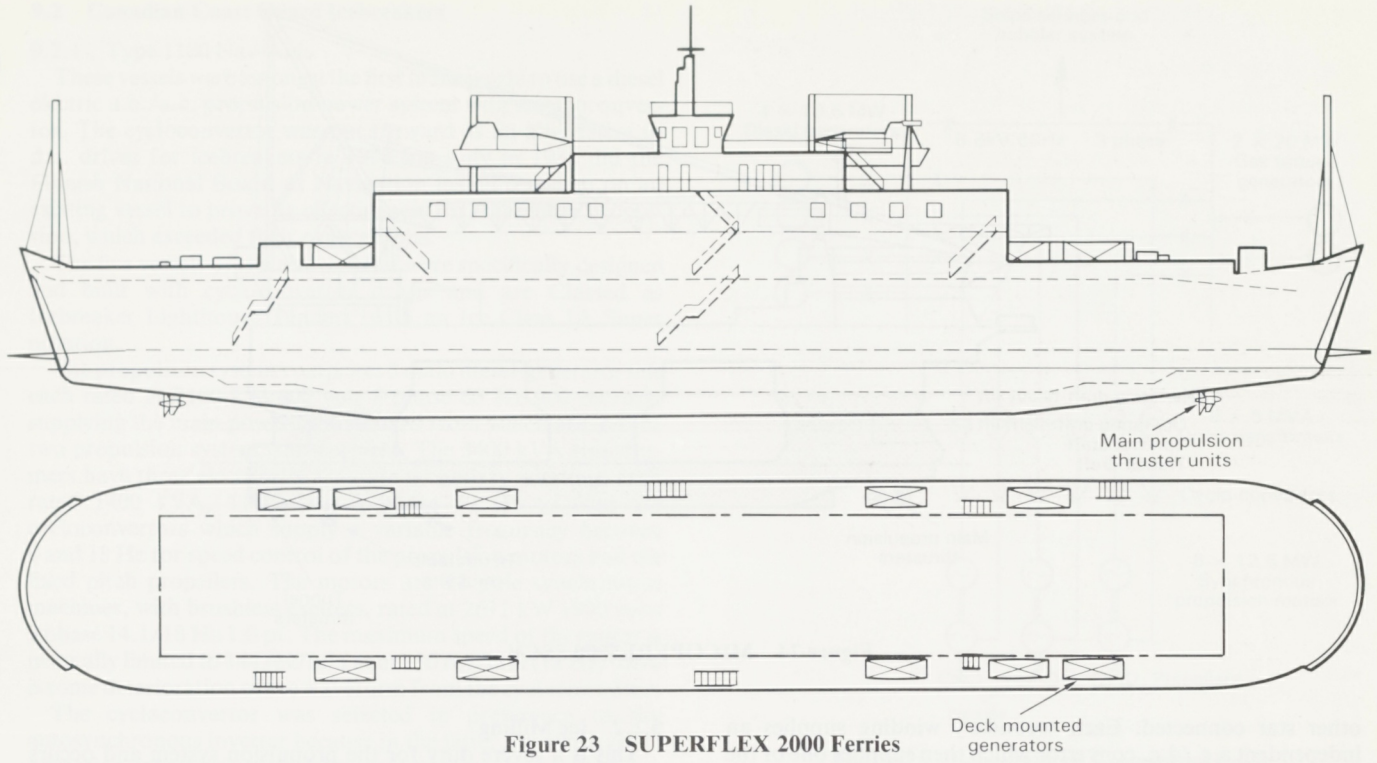


Figure 23 SUPERFLEX 2000 Ferries

with the generating plant that makes these vessels interesting. There are two Schottel propulsion units at either end, a total of four, each driven by a variable speed asynchronous squirrel caged rotor induction motor controlled by an auto/forced commutated convertor. The motors are rated at 550 kW each at 440 volts 60 Hz 1800 rev/min.

The generator sets, forming the power station for the motors are located on the main deck within acoustic weather-protected enclosures. There are 10 × 275 kW 440 volts 60 Hz generating sets arranged so that five each feed two main switchboards fitted within the main accommodation block above the main deck.

The machinery layout is such that there are no machinery spaces, except for the propulsion motor rooms and a small pump room, within the hull and therefore the hull can be put to maximum use for the carriage of vehicles. Full advantage has thus been taken of the flexibility of siting of electric propulsion equipment.

As these vessels are intended to operate with minimum crew and no engineering staff on board, the power plant and propulsion system are controlled by an automatic power management system. It is not envisaged that the crew do anything other than "drive" the vessel and tend to the vehicles and passengers.

The electrical system has inbuilt redundancy and is also arranged so that faulty units are repaired by replacement. To coin a phrase in the ships publicity brochure, the ship is built on the "Lego" principle. Repair by replacement is a relatively new concept in the commercial shipping although it is normal practise in the aircraft industry where faulty main engines are regularly replaced by serviced units. It is suggested that the existing classification record and reporting system would have to be adapted to take account of surveyable items, such as propulsion units, generators and prime movers, that will be replaced at regular intervals and transferred between a number of vessels.

8.5 Crane Vessel for "MICOPERI"

This vessel is classed as a Mobile Offshore Unit. However the Rules relating to its power and propulsion plant are technically no different to those for ships. It is a twin pontoon, semi-submersible heavy lift vessel (Fig. 24) with 2 × 7,000 tonne cranes and has dynamic positioning, positional mooring and electric propulsion systems.

Its main central power station comprises 8 × 5.6 MW 10 kV 60 Hz 14 pole generators driven by 12 cylinder GMT A420 514 rev/min diesel engines supplying a main switchboard through vacuum switchgear, which is also used for the 10 kV distribution.

Unlike the other vessels described, variable speed d.c. motors have been chosen for the main propulsion and dynamic positioning, powering Schottel thruster units with fixed pitch propellors.

There are four non-retractable azimuthing thruster units fitted aft which are used both for main propulsion and D.P. Each unit is powered by 2 × 2,250 kW 750 volt d.c. 8 pole motors in tandem. These motors operate at a maximum speed of 770 rev/min in the propulsion mode and 720 rev/min in D.P. mode.

Towards the forward end of the vessel there are fitted four fully retractable thruster units each powered by a 3,000 kW 750 volt d.c. 8 pole motor having a maximum speed of 700 rev/min. Athwartship tunnel thruster units are fitted in each of the bows powered by 2,500 kW 750 volt d.c. 8 pole motors having a maximum speed of 800 rev/min.

All ten thruster units may be used in the Dynamic Positioning mode which would require a total of fourteen a.c./d.c. convertors in operation. During D.P. operation each thruster may be operating at a different speed.

The tunnel thruster motors are reversible but the azumuthing thruster motors are unidirectional which means any change of direction of the vessel during either mode can be achieved by a combination a change of motor speed and thruster rotational angle. In the propulsion mode the aft thruster units would serve as the steering gear.

The a.c./d.c. convertors are supplied through transformers at 660 volts 60 Hz and in view of the number that may be operated at any one time attention had to be paid to the distortion to the a.c. voltage waveform.

To reduce the distortion the convertors were arranged to operate as 12-pulse units and to achieve this each transformer has two independent secondaries, one delta connected and the

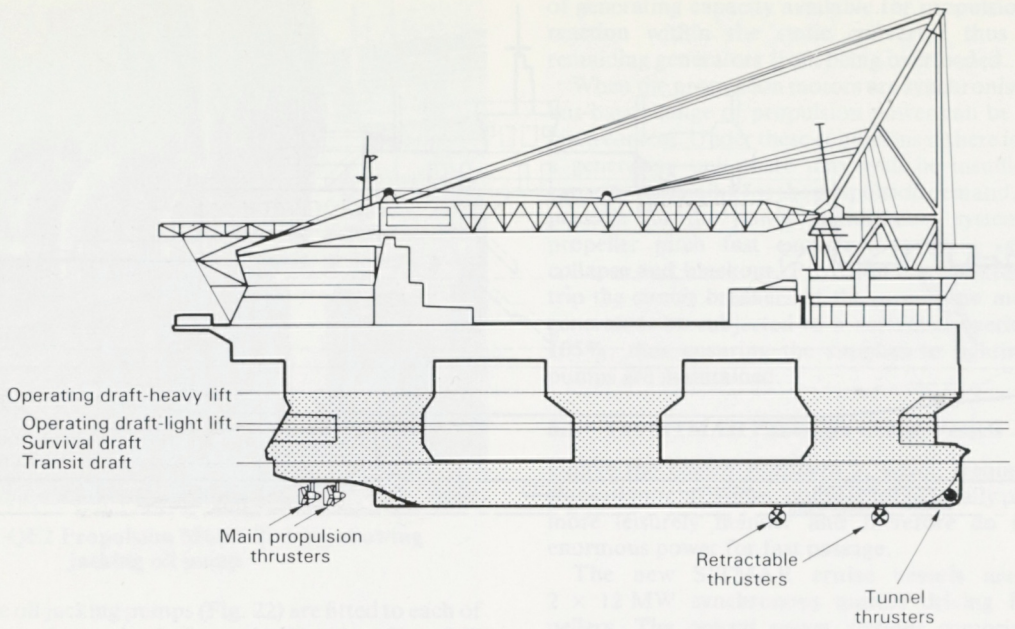


Figure 24 MICOPERI 7000 SSCV

other star connected. Each secondary winding supplies an independent a.c./d.c. convertor which then supplies one of the motors.

The electronic logic circuitry is co-ordinated to ensure each set of motors operate at the same speed. In the event of one of the convertors failing the remaining motor of the set may continue operating, be it at a reduced power.

9. ICEBREAKERS

9.1 Operation

9.1.1 Level Ice

Unlike other electrically propelled vessels which normally only operate in clear open waters an icebreaker has to, in addition, operate in various ice conditions.

There are two steady state operating conditions, moving forward in:

(a) open water

and

(b) level ice.

The propulsion plant would normally be sized to accommodate the power demand for (b). The power requirements for open water cruising would be 10–20% of that available for (b) dependant upon the vessels specified open water speed.

The level ice may be up to about 2 metres thick, as in the case of the Canadian Coast Guard Conceptual Polar Icebreaker. Account also has to be taken of local variations in the thickness and resistance of the ice and of the blocks of ice that are under the ship which may impact on the propeller.

In order not to exceed the stress limits of the propellers and shafting system and so as not to overload the generating plant the convertor driving the propulsion motors would be designed to automatically limit the power and torque available at the propeller.

The propeller speed would be controlled so as to prevent overspeeding and in the event of a speed reduction, due to an overload and torque limit, arranged so as to recover quickly. If the speed falls too low the torque may fall below the level required to break the ice and the ship's forward motion would be impeded.

9.1.2 Ice Milling

This is a severe duty for the propulsion system and occurs when the icebreaker is moving forward in thick ice. When a block of ice passes the propeller the ice load torque varies cyclically at a frequency corresponding to the blade frequency with account being taken of the varying blade area as it passes through the ice. When the propeller impacts the ice its speed would be reduced rapidly and the torque would be allowed to increase to its limit, which may be two to 2.5 times rated torque. At a pre-set threshold value of propeller speed the ice milling torque is reduced to allow the speed to stabilise. The removal of the ice loading allows the speed to recover and at the end of the milling period the motor accelerates to its service speed.

The system load may be controlled and reduced by the combination of increased motor torque and reduced motor speed, thus preventing overloading of the prime mover and drop in frequency.

9.1.3 Stalled Propellers

In the event of the propellers being completely blocked by ice, the propulsion system may be designed so as to permit rapid forward and reverse torques to be applied to the propeller to assist in its release. These torques may be of the order of twice rated torque and be applied in a defined cycle so as to produce a "hammer" effect. In defining the cycle, account would be taken of the thermal capacity of the thyristor bridge as this may be a limiting feature.

9.1.4 Ice Ramming

To assist in breaking the ice the vessel may perform a number of ramming cycles. A typical cycle would be to:

(a) reverse the vessel from the ice to such a distance as would permit vessel to achieve predetermined impact speed
(b) propel the vessel full power ahead until impact
(c) bring ship to rest in ice within predetermined distance
(d) reverse the vessel from the ice.

In practice, this cycle would be performed at the discretion of the ship's Captain, taking into account the response time of the propulsion system/vessel and maximum transientory torque available. In the deceleration mode, account would have to be taken of the regenerative power. In a multi-shaft system, the deceleration of the shafts may be sequenced to limit the regenerative power.

9.2 Canadian Coast Guard Icebreakers

9.2.1 Type 1100 Nav-Aids

These vessels were amongst the first in the world to use a diesel electric a.c./a.c. propulsion power system with a cycloconvertor. The cycloconvertor was put forward as an alternative to d.c. drives for icebreakers in 1978 but only in 1983 did the Finnish National Board of Navigation install a system on an existing vessel to prove its effectiveness for icebreaker propulsion, which exceeded their expectations.

The five vessels of the above series were specifically designed and built with cycloconvertor drives and are Classed as Icebreaker Lighthouse Tenders' with an Ice Class 1A Super notation.

The propulsion system comprises 3 main diesel-generator sets each rated at 2100 kW 600 volt 3 phase 60 Hz 900 rev/min supplying the main power switchboard from which are fed the two propulsion system transformers. The 3400 kVA transformers have three electrically separate secondary windings each rated 1400 kVA, 1100 volts 3 phase 60 Hz to feed the cycloconvertors which supply a variable frequency between 0 and 18 Hz for speed control of the propulsion motors and the fixed pitch propellers. The motors are 12 pole synchronous machines, with brushless exciters, rated at 2611 kW 1900 volts 3 phase 14.1/18 Hz 1.0 pf. The maximum speed of the motor is normally limited to 144 rev/min as at 180 rev/min (18 Hz) there is some deterioration of the waveform from the cycloconvertor.

The cycloconvertor was selected in preference to the autosynchronous inverter because in the latter, by virtue of its operation, produces essentially an output current which is a square wave, not sinusoidal, that contains harmonics. These harmonics can give rise to air gap torque excursions of the order of ± 20% of the mean torque. Also at low speeds when the convertor is forced commutated these torque excursions may be as high as ± 100% of the mean torque with an air gap torque frequency in the case of the 6 pulse bridge of six times motor frequency.

It is possible that this excitation torque, which varies with motor speed, could resonate with the natural frequency of the mechanical system. If the speed at which this resonance occurs is at a low value, when forced commutation is necessary, and where mean output torques of 200% are required, there is a possibility of mechanical failure of the shafting system and/or motor parts.

As the cycloconvertor output current waveform is very close to a sine wave the torque harmonics in the motor air gap are significantly lower at approximately ± 6% at full speed. These harmonics, assuming normal level of system damping, should not excite a resonance of the mechanical natural frequency such as to give rise to damaging levels of vibration.

9.2.2 Type 1200 Icebreaker

This vessel is a larger version of the Type 1100 vessels having 3 × 5000 kW 4160 volt 3 phase 60 Hz generators supplying two cycloconvertor fed 6000 kW synchronous motors, which power fixed pitch propellers.

9.2.3 Conceptual Polar Icebreaker

Mr. W. A. McCloy of the Canadian Coast Guard suggests in his paper[22] that the design of a vessel was being considered for operation in the Canadian Arctic and that such a vessel would be designed to operate within the Arctic Ocean, for approximately 300 days per year when severe sea ice and weather conditions prevail. It would have the capability of maintaining progress through consolidated ice of mean thickness about 2m at a speed in excess of 2 knots, to penetrate ridges of up to 9m sail height by ramming and have an open water speed of the order of 19 knots. To satisfy these requirements would require a continuous power at the propellers of the order of 74 MW.

In common with existing heavy icebreakers a triple fixed pitch propeller arrangement is being considered with each propeller designed to absorb a third of the total propulsion power i.e. 25 MW continuous.

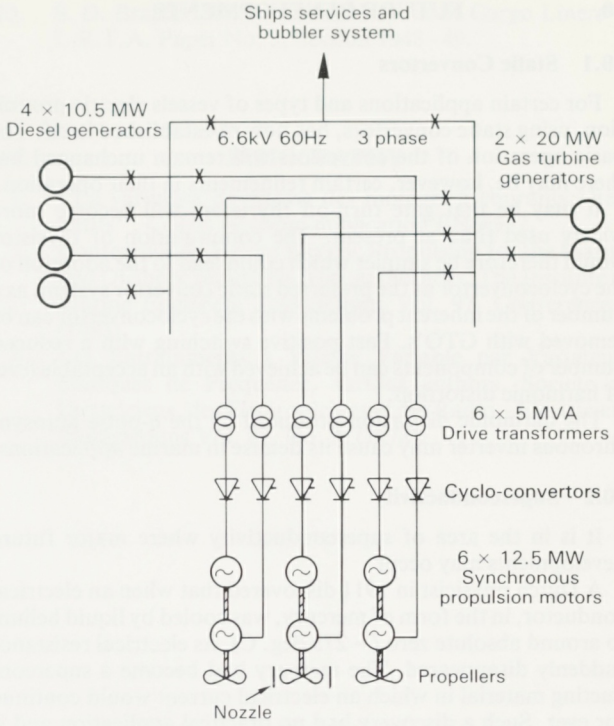


Figure 25 Schematic of Conceptual Polar Icebreaker Propulsion System

The contra-rotating wing propellers would be exposed with the centre propeller, which would be of a lighter construction than the others, enclosed by a fixed nozzle and able to produce approximately 40% more thrust than the wing propellers for the same power. The centre propeller would be designed essentially to overcome the hydrodynamic loading of the vessel, and because of the nozzle would not mill ice.

A combined diesel/electric, gas turbine/electric system is suggested to drive the three fixed pitch propellers (CODEAGE) with speed control effected by cycloconvertors (Fig. 25). Because of space limitations in the ship and in order to obtain the necessary power, 2 × 12.5 MW synchronous propulsion motors in tandem per shaft would be required.

Each motor would have its own cycloconvertor with provision made to synchronise them in pairs for each set of motors and also to synchronise and synchrophase between each pair of motors. This would be a complex problem requiring careful engineering. Should one bridge be incorrectly switched it may cause failure amongst the remaining convertors.

The ship's central power station, comprising of gas turbine and diesel generating units, would be arranged to operate in parallel to supply the high voltage main switchboards.

Gas turbines, derived from the aero-engine, are being considered because of their high power/weight ratio, which would be of major concern with a vessel of this size having such a massive propulsion power plant approaching that of *Queen Elizabeth 2*. Because of their high fuel consumption it is envisaged the gas turbines would only be used when powers in excess of 40 MW are required during ice manoeuvres and under these conditions they would not operate in parallel with the diesel generating sets but be connected to separate switchboard bus-sections supplying different sets of propulsion motors.

A nuclear reactor could be used to supply steam to drive turbo-generators as an alternative to the above, but in most countries of the world public opinion would prohibit such an arrangement.

10. FUTURE DEVELOPMENTS

10.1 Static Convertors

For certain applications and types of vessels electric propulsion, using static convertors, has now re-established itself. The basic operation of the convertors will remain unchanged but there may be, however, certain refinements in their operation.

It may be that gate turn-off thyristors will become more widely used than at present. The commutation of thyristor would therefore be simpler which could lead to the adoption of the cycloconvertor as the preferred static convertor system, as a number of the inherent problems with the cycloconvertor can be removed with GTO's. Fast positive switching with a reduced number of components can be achieved with an acceptable level of harmonic distortion.

The harmonic distortion produced by the 6-pulse autosynchronous inverter may cause its demise in marine applications.

10.2 Superconductivity

It is in the area of superconductivity where major future developments may occur.

A Dutch physicist in 1911 discovered that when an electrical conductor, in the form of mercury, was cooled by liquid helium to around absolute zero (– 273 deg. C), its electrical resistance suddenly disappeared. The mercury had become a superconducting material in which an electrical current would continue for ever. Such a discovery had no practical application and it was not until during the 1960's that a superconductor of niobium-titanium was developed.

Based upon this alloy of niobium (53.5%) and titanium (46.5%), which became superconducting at around 4.4 deg K, machines were developed in the UK and USA. These superconducting machines were d.c. homopolar motors, cooled with liquid helium, in which very high magnetic fields could be developed within the windings of the machine without the use of magnetic iron and with no power loss. The homopolar d.c. motor is the most basic of all machines having just two field windings and a simple armature, similar to the battery driven motors in children's toys.

The advantage of the superconducting homopolar motor is that it can produce very high torques, sustain large overload conditions more readily than any other electrical machine and is extremely robust. The magnetic flux density is very much higher than a conventional machine as it is not limited by the quality of the magnetic iron.

In Japan an electromagnetic thruster (EMT) is being developed which would operate in a manner similar to the linear motor propelled train. It is proposed superconducting coils be built into the ship, which are then energised to cause a reaction with an electric current in the seawater producing a thrust and thus propelling the ship along. Such a propulsion system would require no propellers which would be attractive for icebreakers.

The big disadvantage with the above schemes is that a sizeable refrigeration plant may be required to produce and maintain liquid helium at 4.4 deg K (– 268.6 deg C). In recent months however researchers in the USA have reported obtaining superconductivity in a ceramic mix of barium carbonate, yttrium oxide and copper oxide at – 179 deg. C. In China a ceramic has been made with traces of superconductivity at – 58 deg. C and in Japan superconductivity at room temperature 14 deg. C has been hinted at.

It is theoretically possible to obtain superconductivity at or about normal ambient temperatures but this will involve ceramics rather than metals and their alloys. Such a discovery would be one of the most important in modern science and its application for commercial marine electric propulsion would be dependent upon business economics and advantages. It may be that the first superconducting propulsion motor will be installed in a government owned vessel, but this is a matter of speculation.

11. CONCLUSION

In conclusion the author would reiterate Mr. Brands poem:[23]

'The electric man needs little space —
half the nuts and bolts
He profits by the product of
the amperes and the volts;
But, dictum in high places has
for ever laid it down,
That shipboard electricity
must never wear a crown;
For Power produced in Boilers and
converted into Watts,
Must be converted back again
before expressed in Knots.''

12. ACKNOWLEDGEMENTS

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Discussion

on the paper

ELECTRIC PROPULSION :

A REVIEW

by

B. P. SHARMAN

Paper No. 2 Session 1987-88.

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Any opinions expressed and statements made in this Discussion Paper are those of the individuals.

Hon. Sec. A. G. Gavin
71 Fenchurch Street, London, EC3M 4BS

Discussion on the Paper

ELECTRIC PROPULSION : A REVIEW

by

B.P. Sharman

DISCUSSION

From Mr J. K. Robinson

I would like to thank the Author for his up-to-date comprehensive review of electric propulsion. As such vessels are not commonplace, nor is their building confined to any particular shipyard, it should be a useful reference work for our colleagues in the Outports. For their further assistance I would request that the Author expand section 6.5 by illustrating the problems that can arise from the increasing use of solid-state convertors.

The recent scientific breakthrough in superconductivity has given rise to much journalistic speculation. As the Author points out it was some 50 years before the first large motor drive was installed on a trial basis in a power station by Southampton Water. Existing technology at liquid helium temperatures employs very finely drawn niobium titanium wires embedded in a copper matrix and the cost of poor reliability of the vacuum insulation system and cryogenic plant has been a major barrier to general application.

The materials now identified as superconducting at temperatures above liquid nitrogen (e.g. $YBa_2\ Cu_3\ 0_7$) remove this barrier, but considerable development work is required before these polycrystalline, fragile and imperfect ceramic materials, which only remain super-conducting at relatively low current densities can be utilised at sea.

From Mr N. A. Hall-Stride

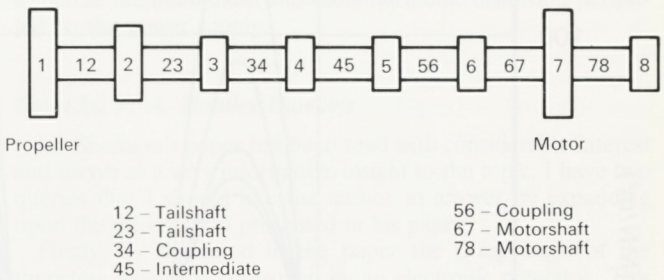
I'm always pleased to see the word 'Review' in any paper title, as this usually means that the Author has done much of the ground work for us, both in compiling a list of useful references and also in producing what usually turns out to be a stand alone guide to a particular subject area. Brian Sharman's paper, I think, performs this role very well.

I was particularly interested to read Chapter 9 in the paper concerning the operational requirements of Icebreakers. The Advanced Engineering Services group recently undertook a study of the transient torque considerations of the shafting system of one of the vessels mentioned; the Type 1200 Canadian Coastguard Icebreakers.

The shafting system had come through the normal Society plan approval channels; subject to the usual alignment, axial, lateral and torsional vibration analysis procedures; and been found to be satisfactory. It was the electrical motor builders, Canadian General Electrical, who asked the question as to whether the transient air gap torques resulting from line-line short circuit currents had been considered. They had not, of course, nor was there any Rule requirement to do so. Canadian General Electric provided a torque/time history for the motor under this fault condition; the excessive magnitude of torque they were predicting prompting immediate investigation on our part. The supplied torque/time history was thus used as input excitation to a finite element model of the shaft system.

The finite element method, the MSC/NASTRAN code in this case, was particularly suited to this problem, permitting comprehensive time and frequency dependent loading, as well as full specification of system damping. Figure D1 illustrates the system idealisation of major inertias and stiffnesses, only the torsional degree of freedom being released. Figure D2 illustrates the excitation torque/time history, shown dotted, varying between +4 and −8 times the normal full load torque. With this excitation input at the motor station, 7, the overall system response torque, shown solid, resulted. Considerable torque amplification was noted, reaching approximately ±11 times normal full load torque. Low system damping, the order of 3.3% of critical, together with proximity of the excitation frequency and the motor pole passing frequency to the system first torsional resonance, being the major contributory factors to this.

Figure D1 Discrete Mass-elastic System



In terms of allowable stress levels, the Ice Class Rule philosophy; whereby the outer fibres of propulsion shaft are permitted to reach yield stress on the Von-Mises criterion, was adopted. Assuming a purely torsional regime then, the maximum shear stress is limited to:-

$$\text{Maximum Shear Stress} \leqslant \frac{\text{Yield Strength}}{\sqrt{3}}$$

Converting the observed torsional response to shaft section shear stresses, as illustrated by Figure D3, and with the allowable stress levels as presented above, it was noted that one

Figure D2 Torque – Time History

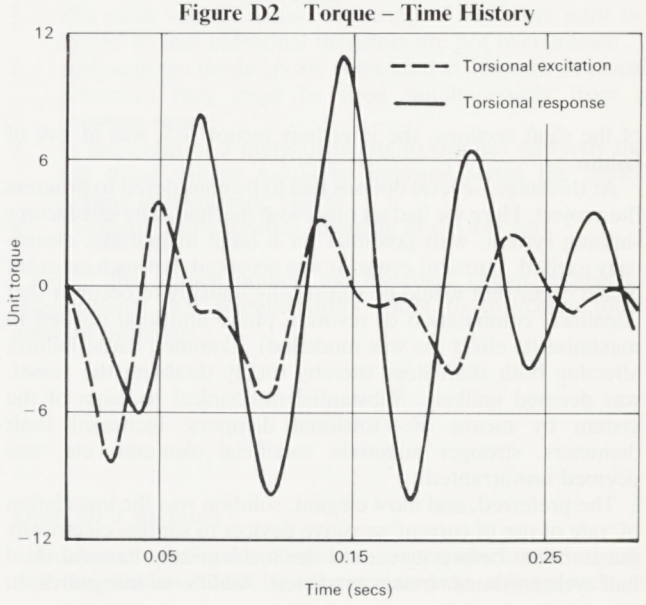
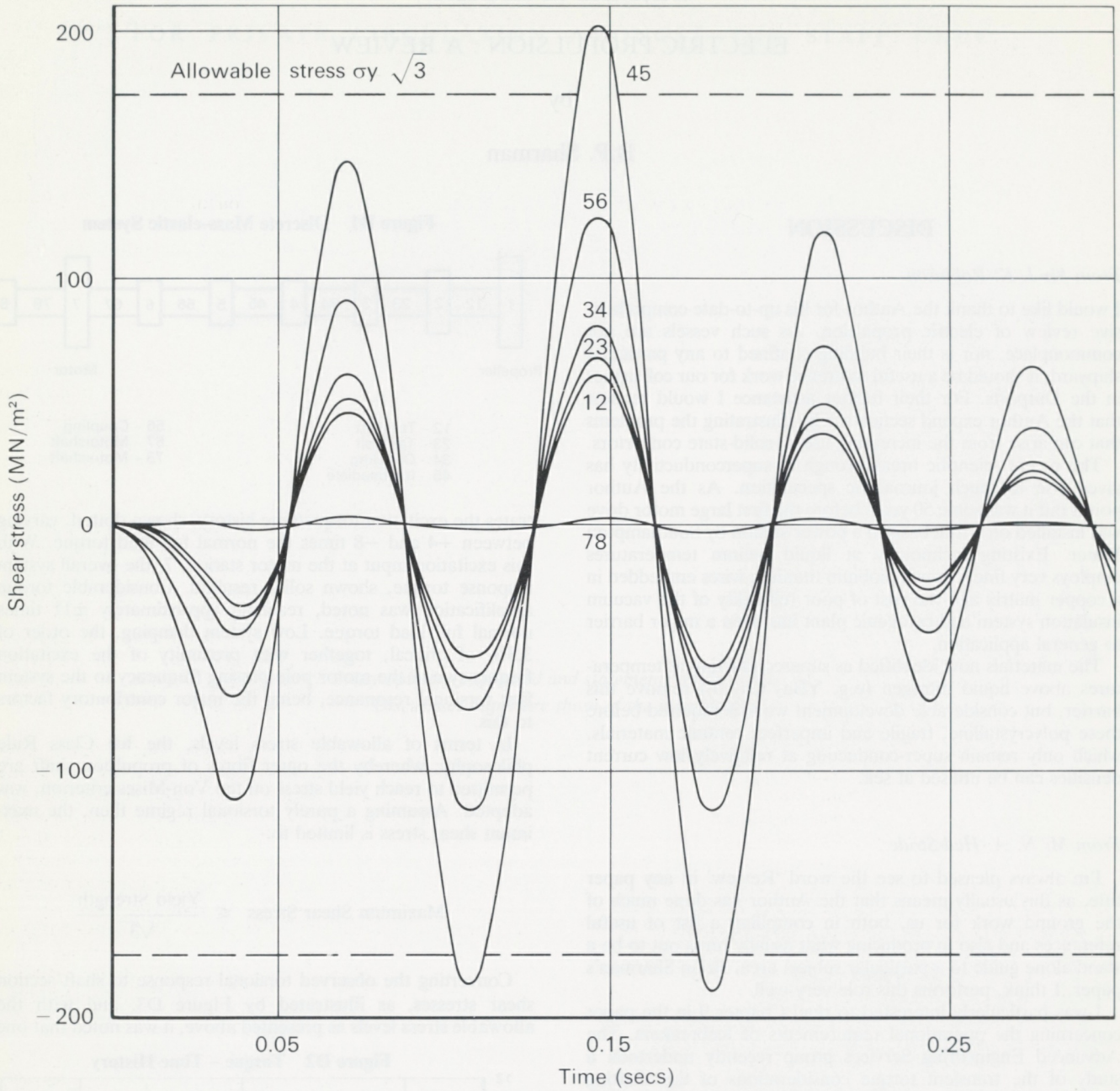


Figure D3 Transient Stress Response



of the shaft sections, the intershaft section 4-5, was at risk of failure.

At this stage, several options had to be considered to progress the project. Here we had an otherwise mechanically satisfactory shafting system, with potential for a large magnitude, electrically excited, transient event. It was accepted that such an event would occur, but would be statistically unlikely to occur at that 'idealised' combination of rev/min, phase and load needed to maximise its effect (as was modelled). Common cause failure, affecting both shaft lines thereby totally disabling the vessel, was deemed unlikely. Substantial mechanical redesign of the system by means of:- torsional dampers, increased shaft diameters, stronger materials, sacrificial elements, etc, was deemed unwarranted.

The preferred, and most elegant, solution was the installation of 'rate of rise of current' sensitive devices to supress electrically the transient before it reached the mechanically harmful third half cycle torsional stresses predicted. Additional safeguards, in the form of a mechanical torque limiting coupling, were however subsequently fitted.

Reference [1]

From Mr R. G. Roberts

The impression that the effects of harmonics have suddenly burst on to the electrical engineering scene should not be allowed to grow.

Harmonic currents exist on all electrical distribution systems where thyristor convertors are installed, and within the U.K. they have been observed on our electricity grid system since the 1960's. There were discussions between major users of such convertors and the area boards in the late 60's and early 70's. These discussions have culminated in limits being put on the level of harmonic current that a manufacturer's equipment or industrial site can inject in to the electrical system.

These limits may not easily be applied to ship-board systems

as the proportion of the capacity of harmonic producing equipment, to the total generating capacity can be very large. An extreme example is the Superflex ferry.

A system designer is in a position to predict the likely level of harmonic disturbance, but since the relevant electrical parameters are not always known with great accuracy, he may be wrong. Usually the exact level of harmonic disturbances can only be determined by measurement and any corrective action taken after a vessel has been in service for some time.

Possible corrective actions can include installation of a filter, segregation of sensitive supplies by design, or designing the electrical equipment to be capable of operation without adverse effect, e.g. oversizing motors. Any corrective action may not remove all possible effects of harmonics. A filter may cause other adverse effects elsewhere on a system, like resonance effects. Segregation may not be possible as items like lights can fail due to high harmonic levels. Increasing the size of motors and etc. costs money.

Perhaps, arising from Mr Sharman's work on harmonic levels, the Society could be better qualified to advise on potential problems with the use of solid state convertors.

From Mr R. E. Gibson

I would like to congratulate Mr Sharman on an interesting and well prepared paper.

Page 11, paragraph 6.3.2 of the paper refers to the effects of generator reactance on the system short circuit fault level, and the penalty of high generator reactance on motor starting conditions. An equally important consideration, since electric motor drives are involved, is the stability of the system i.e. the ability of the system to rise through a system voltage disturbance. A high source reactance leads to low short circuit fault level but also poor system stability.

Page 13, paragraph 6.4.3 refers to differences between H.V. switchboards and M.V. switchboards with respect to segregation. Segregation is an important consideration with M.V. switchboards, particularly if in-service maintenance is necessary and for the containment of short circuit or fire damage: IEC 439-1[(2)] lists the different forms of segregation that may be provided.

Page 16, paragraph 6.5.2 refers to the problem of harmonic distortion, it would be interesting to learn of any National or International Standards which give guidance on maximum levels of harmonic distortion. A paper dealing with shaft generators by R.T.S. Locock, M.J. Wood, W.T. Blyth[(3)]refers to MOD(N) requirements for individual harmonics not to exceed 3 per cent of the fundamental and the total harmonic content not to exceed 5 per cent of the fundamental.

An alternative solution for reducing the effects of harmonic distortion may be, as other authors have suggested, to segregate those loads which are harmonic sensitive, e.g. communications, and instrumentation and supply these from 'clean' supplies.

From Mr J. L. Buxton

I only wish to raise a supplementary comment following on from the points raised by other contributors regarding the problems of harmonic distortion.

It would appear that there is very much a situation of "devil take the hindmost" when it comes to the manufacturers of electronic control equipment, i.e. the attitude seems to be "this is the quality of power supply provided; make your equipment work on it".

As a result manufacturers are now required to demonstrate that their programmable electronic equipment will operate satisfactorily with a permanent voltage variation of ±10%, a permanent frequency variation of ±5%, a voltage transient of ±20% and a frequency transient of ±10%.[(4)] In addition they must demonstrate that the equipment is not susceptible to EMI over a frequency range of 50Hz to 200MHz and that it will withstand transients on the power lines of 500V having a rise time of 5 ns and pulse duration of 100 ns.

While these test conditions are severe it would appear that they may not be sufficient and we must also introduce additional tests to demonstrate satisfactory operation of equipment with excessive waveform distortion on the power supply and a slower pulse transient to take account of thyristor switching.

In order to determine the conditions for a waveform distortion test it would be necessary for the electrical engineers to define the mamimum allowable harmonic distortion permitted on the power supply.

From Mr P. A. Huntley-Hawkins

Mr Sharman's paper has been read with considerable interest and serves as a very informative insight to the topic. I have two queries that I should like the author to answer by expanding upon the information presented in his paper.

Firstly, as illustrated in the paper the firing angle of the thyristors would be controlled by an electronic regulator. This system ensures the currents and voltages applied to the motor are correct to provide the shaft torque and speed outputs that are necessary to maintain the driven load in the state demanded by the reference. For examples in other applications, winder drum drives would be equipped with a speed control regulator such that the motor torque produced would be sufficient to hold the rope speed to the level set by the driver, whatever load may be carried in the conveyance, and excavator drives may be provided with a constant "power" characteristic to ensure that the equipment is always used to its maximum capabilities whatever the load demand may be.

When applying electric drives to propel ships a differing set of load and speed conditions are envisaged dependent upon the type of ship and the propulsion unit. Could the author please expand on the hints given in his paper as to the speed and torque requirements for the driven units quoted in Section 3 and the overall regulator characteristics of the noteworthy systems referred to in Section 8. Secondly it is noted from the cycloconvertor power schematic diagram of Figure 5 that individual bridge arms may be composed of a series string of thyristors. In other electric drive applications this practice has been avoided due to variations in device characteristics causing system malfunctions and eventual device failure. The main problem areas requiring a solution are :-

1. The peak voltage across the string of thyristors must be shared so that individual thyristors are not overstressed.
2. Although the thyristors are connected at different electrical potentials they must be fired simultaneously from a common source.
3. In the event of a thyristor failing to conduct correctly the full string voltage would be imposed across the device leading to immediate failure.
4. Thyristor characteristics changing as devices age.

Could the author outline the electrical circuit protection arrangements that manufacturers adopt to overcome these inherent problems.

From Mr J Atkinson

I enjoyed reading Mr Sharman's paper which must signify that the author should be congratulated on writing such an

interesting and comprehensive review on the subject of electric propulsion. The paper, I am sure, will be a useful reference document for many years to come.

During the erection of the QE2 propulsion motors for their factory test it was noted that with the high pressure jacking oil pumps in operation, it required very little manual effort to turn the 105 tonne rotor. This could present a problem in service with an electric drive, particularly on ships with fixed pitch propellers or even those with controllable pitch propellers which are not fully closed, in as much that undercurrents or water flow could turbine the propeller causing the rotating system to turn. A well known law, whose name escapes me for the moment, could no doubt apply if the rotor was turned in the opposite direction to that required for starting and consequently causing problems.

Perhaps the author could advise if any precautions are taken to prevent such circumstance or even if that circumstance is in practice, imaginary.

Even though electrical machines are considered highly efficient equipment their losses are always of great concern and specifications frequently capitalize on them. The copper losses induced in the windings are a function of operating temperature and I wonder whether this or any of the other losses are ever taken into account during the feasibility/appraisal study. The author's comments on this point would be interesting with particular reference to the QE2 installation since the cooling water at 38°C is hot and if sea water was used, quite a reduction in copper losses could be achieved.

From Mr G R Styring

I must congratulate the author on the presentation of such a well researched paper which I have found not merely interesting but educational.

Several references are made to power management systems and recent experience indicates that these can achieve a high degree of reliability but that some "central power stations" which they control have fundamental design shortcomings.

This was recently highlighted in the case of "Challenger" a crane-ship with approximate installed capacities as follows:-

AC generators: 13.5MW 0.8 power factor

DP system (thruster and anchors): 11.2MW variable power factor

Crane 6MW: variable power factor

The DP system employs squirrel cage induction motors and the crane drives are SCR to d.c. motors, resulting at times, in system power factors of 0.1 or worse.

To obviate problems of lack of VAr capacity the power management generator MW start margins were set such that, in certain modes, at least four out of five sets were paralleled but running on only 10/15% of their full MW load capacity.

Less close hand experience indicates that similar problems have been experienced with the "Superflex" ferries referred to in the paper.

It happens that both "Challenger" and the "Superflex" ferries were built by the same yard and it appears to me, on information available, that the electrical equipment was specified and bought in on a piece meal basis and without an adequate overall consideration of system design.

It is of interest to note that in the case of the Trinity House vessel "Mermaid", having about 2.4MW of main propulsion and the thruster SCR Drive to d.c. motors, one manufacturer supplied the propulsion and the thruster motors, power management system and the generators rated at 0.6 power factor. One may speculate whether or not the specification of this power factor rather than the "traditional" 0.8 resulted from one manufacturer being in a position to make an overall appraisal of the system.

Does the author consider that there is an urgent need for a Rule change requiring an overall, rather than piecemeal, appraisal of generation systems and load characteristics, with particular reference to VAr compatability, in the cases of vessels with electric propulsion or specialised electrical loadings?

In this connection I include an extract from "Guidelines for the specification and operation of dynamically positioned drilling vessels (1982)" issued by the Petroleum Engineering Division of the U.K. Department of Energy:-

> "3.3.1 power systems should provide for generators to be run at power factors which effectively match the characterstics of the Power Sources".

AUTHOR'S REPLY

To: Mr J.K. Robinson

Traditional electro-mechanical systems are being replaced by solid state electronic systems some of which are processor based. These new systems are susceptible to externally-generated electrical interference such as RFI. As the functional complexity of systems has increased, so electrical interference may cause the system to fail in complex failure modes.

Where electronic systems are not used for safety functions electrical interference may only prove to be an annoyance such as crackling on a radio set, however, electronic systems are increasingly being used for safety functions and in such situations electrical interference may cause deleterious malfunctions. Spurious signals caused by RFI on a radar set may be incorrectly interpreted by the operator and navigational equipment may give incorrect readings or even cause shutdown if microprocessor based. Satellite signal reception equipment may be unable to function due to the RFI swamping the low level of input signal.

Incorrect fire or engine alarms may be initiated by pulse interference due to SCR switching, main engine speed control equipment can be affected giving rise to speed variations and incorrect readings from gauging systems.

Solid state automatic voltage regulators may experience voltage fluctuations due to interference contamination which could lead to unstable operation of the electrical generating plant.

Many functions which were once handled by more conventional means are progressively being taken over by microcomputer based programmable electronic systems (PES). Digital computer data and signals within a PES are generally time multiplexed down common highway bus and the effect of an interference pulse on this type of arrangement would be difficult to predict. A highway bus may contain data, address and control functions and the effect on these would be dependent upon the timing of the interference pulse in relation to the computer's internal clock, the part of the program being executed and the information on the bus.

It may be that the effect of an interference pulse on a PES has an immediate reaction or alternatively the bus data or contents of a memory could be corrupted and not be known about until the data in question is acted upon at a much later date.

Lower order harmonic disturbances give rise to frequency dependant equipment drawing higher currents which may give rise to increased temperatures. Generally motors and generators can operate with a distorted waveform without any deleterious effects as they are being continuously forced cooled by fans. Transformers may be less well equipped to accommodate additional heating. In practice the most frequency sensitive equipment appears to be fluorescent lamps having a capacitive and inductive ballast system which tend to draw a greatly increased operating current. These increased currents are cumulative and may cause overloading of the lighting transformer which would in general only be rated for normal conditions.

The 5th and 7th harmonics from a 6 pulse convertor both produce a 6th order harmonic torque in the driven propulsion

motor. The 5th harmonic currents are backward rotating and therefore passing the rotor at 6 times frequency whereas the 7th harmonic is forward rotating also passing the rotor at the same frequency. This torque, along with the 12th and 18th harmonic torques, may cause torsional resonances in the motor shaft system should its natural frequency be of the 6th order.

To Mr N.A. Hall-Stride

The line-line short circuits referred to were caused by convertor malfunction. On subsequent vessels it has been the practice to install high speed circuit breakers in the supplies from the convertor outputs to the motors to protect against convertor internal faults. In a.c./a.c. systems where the convertor operates at an output frequency substantially less than the supply frequency, d.c. circuit breakers may be required to be fitted as the performance of a.c. circuit breakers is frequency dependant.

Whilst statistically line-line short circuits may occur within the motor terminal box, provided the terminations are correctly made, the probability is sufficiently low as not to be considered a problem.

To Mr R.E. Gibson

It is agreed a high source reactance may lead to poor system stability. Transient voltage oscillation may be calculated by the following formula:-

$$U = \frac{Ims\ x'd}{Ims\ x'd + n\ Ing\ (1\text{-}K_0)} \times 100$$

where

U – voltage oscillation (%)
Ing – generator rated current
x'd – generator transient reactance
n – number of generators parelleled
Ims – motor starting current or disturbance current
K_0 – preliminary loading coefficient of generators

A high generator transient reactance or a sudden application of a disturbance current can give rise to high voltage oscillations. The disturbance current may arise when the ships propellers are in and out of the water during heavy seas. In the case of a convertor fed propulsion motor this should not present a problem as the convertor response would soften the disturbance effects. Propulsion motors being supplied directly from the main switchboard may however result in system instability. This, it is understood, was experienced on the QE2 whilst operating with 6 generators during heavy seas and in order to make the system more stable the remaining 3 generators were paralleled onto the system, i.e. increasing 'n' in the above formula.

It is agreed segregation in switchboards is an important consideration however, compared with h.v. it is not unusual for an m.v. switchboard to be unsegregated particularly the older style custom built switchboards constructed by the smaller manufacturer. The modern modular switchboard lends itself more readily to segregation.

So far as is known there are no national or international standards which give guidance on maximum levels of harmonic distortion for marine systems. It is understood the MOD(N) figures were imposed by the designers of the weapons systems being the maximum distortion their equipment could withstand. Work being carried out in IEC also proposes the MOD(N) figures but Moltgen[5] suggests it is not unreasonable to limit the permissible total harmonic content to 10% and the rms value of individual components, up to the 15th order, to 5% of the fundamental; at the same time permitting instantaneous deviations up to 20% of the fundamental line voltage.

The effects of harmonic distortion may be reduced by supplying sensitive loads from clean supplies. Some recent ships have fitted motor/generator sets specifically for this purposes.

Mr J. L. Buxton

There is work currently being carried out in IEC to specify the power supply characteristics for which electrical and control equipment is to be suitable. It cannot be guaranteed however that a power system containing convertors could be initially designed to meet these criteria. The final waveform is also influenced by the parameters of the installed electrical system. In addition to the harmonic distortion already discussed there may be post commutation 'ringing', from the switching SCR's, and in the autosynchronous inverter, subharmonics and super-harmonics resulting from the beat frequencies between the fixed frequency supply bridge and variable frequency machine bridge.

It is not suggested therefore the test conditions to which you refer be amended as it is difficult to propose standardized alternatives. A more practical approach would be to do as Mr Gibson suggests and arrange for 'clean' supplies.

To Mr P. A. Huntley-Hawkins

The author is not familiar with the torque/speed requirements for the driven units quoted in section 3 of the paper, it is suggested they are a function of the propeller characteristics which is a matter for the hydrodynamicists. In all cases the units may be driven by an electric motor, diesel engine, gas or steam turbine all of which may be equally suitable as marine propulsion units but have vastly differing torque/speed characteristics. For a convertor fed variable speed electric propulsion motor the characteristics shown in figure D4 would appear to be typical.

To date in marine systems thyristors in series have not proven to be a problem as suggested., To ensure thyristors are not overstressed IEC 92-501[6] specifies the following limiting repetitive peak voltages (U_{RM}) in relation to the peak value of the rated voltage at the input of the semiconductor convertor (U_P).

– when connected to a supply specifically for the propeller drive.

$$U_{RM} = 1.5\ U_P$$

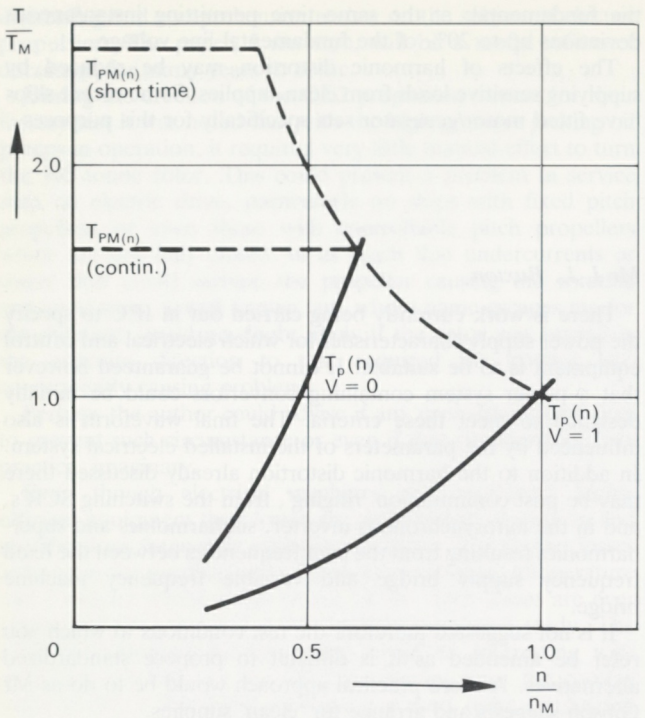
– when connected to a common main supply.

$$U_{RM} = 1.8\ U_P$$

Where the thyristors are connected in series the above values are to be increased by 10%.

One major British manufacturer normally designs with a 'safety margin' of 2.2 for thristors in series. With such an arrangement, if a device were to fail short circuit, as the result of the full string voltage being imposed across it, the remaining devices in the string would be capable of continued operation until the defective unit could be replaced. Also with the above safety margins thyristor aging would not have a significant effect upon the convertor operation.

The thyristor in series may be fired simultaneously using impulse transformers with a common primary.



T_{PM} = Propulsion motor torque
T_P = Propeller torque
n = Propeller rev/min
N = Nominal valves
V = 0 → bollard condition
V = 1 → Free running condition

Figure D4 Torque/Speed Characteristic for Propeller and Propulsion Motor

To Mr J. Atkinson

Shaft brakes may be fitted to prevent the motor rotating whilst the vessel is docked however, in general the high pressure jacking oil pumps for the motor bearings would only be run during motor start-up and stopping. When the motor is stopped the pumps would be switched off and the rotor shaft would seat into its lower bearing shell. It is suggested under these conditions it would require more effort than was noted in the factory to turn the rotor.

Should however the rotor be turned in the opposite direction, to that required for starting, as the excitation supply would be switched off any generated voltage due to residual magnetism within the machine would be minimal. The shaft encoders would signal to the convertor the position of the rotor at the instant when the motor is required to start and the stator windings energised to brake the motor, after which the normal starting procedures would be followed.

There are inherent problems cooling with sea water such as corrosion and the build up of salts on the hot surfaces. Whilst salt water cooling is still acceptable, the modern practice for machinery systems of which electrical generators and motors may form part, is to use a closed loop centralised cooling system using fresh water. This has the advantage that corrosion inhibitors may be added to the water and the temperature of the loop can be controlled to close limits. The temperature of the cooling water for the electrical machines in such a system would be governed by the engine cooling requirements.

To Mr G. R. Styring

Power management systems would appear to have traditionally been considered solely as a means to switch on and off engines according to the load imposed upon them by the electrical generators. What has often been overlooked is that prime-movers see power, i.e. Watts, whilst generators see apparant power, i.e. Voltamperes. If no account is taken of this there is a danger of damaging the generators by exceeding their capacity to supply reactive voltamperes.

This may be demonstrated by the calculation below for a twin shaft vessel slow running at 6.7 knots with a propeller power at 40 rev/min about 333kw at 0.26 power factor per shaft.

Propulsion motor apparent power = $\frac{333\text{kw}}{0.26}$ = 1280kVA

Hotel load = 6500kW at 0.8 power factor
=8125kVA

Total power consumption = 7166kW 10685kVA

Total power factor = 0.67

With two generators connected.
G_A = 7690kW at 0.75 power factor
= 10260 kVA

G_B = 5116kW at 0.75 power factor
= 6820kVA

Engine powers at MCR = 85%
EG_A = 0.85 x 7690kW = 6536kW
EG_B = 0.85 x 5116kW = 4349kW

Power capacity available = 10885kW 17080kVA
Generator loading = 63%
Engine loading = 56%

It can be seen from the above that the lower the motor power factor and the higher its power in relation to hotel load the greater will be the difference between the loading factor of the generator and its engine.

It is agreed when considering the modern power system, which may have variable speed convertor fed electric motors, the possibility of low power factors should be considered and this has been taken into account in Notice No. 1 to Part 6, Chapter 2-1 of the 1987 Rules for Ships.

References

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(3) R.T.S. Locock, M.J. Wood, W.T. Blyth: Conference on Electrical Propulsion and Shaft Generators in Ships, The Institute of Marine Engineers 1975.

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(5) G. Moltgen: Convertor Engineering. An Introduction to Operation and Theory, Wiley/Siemens.

(6) IEC Publication 92: Electrical installation in ships, Part 501: Special features – Electrical propulsion plant.

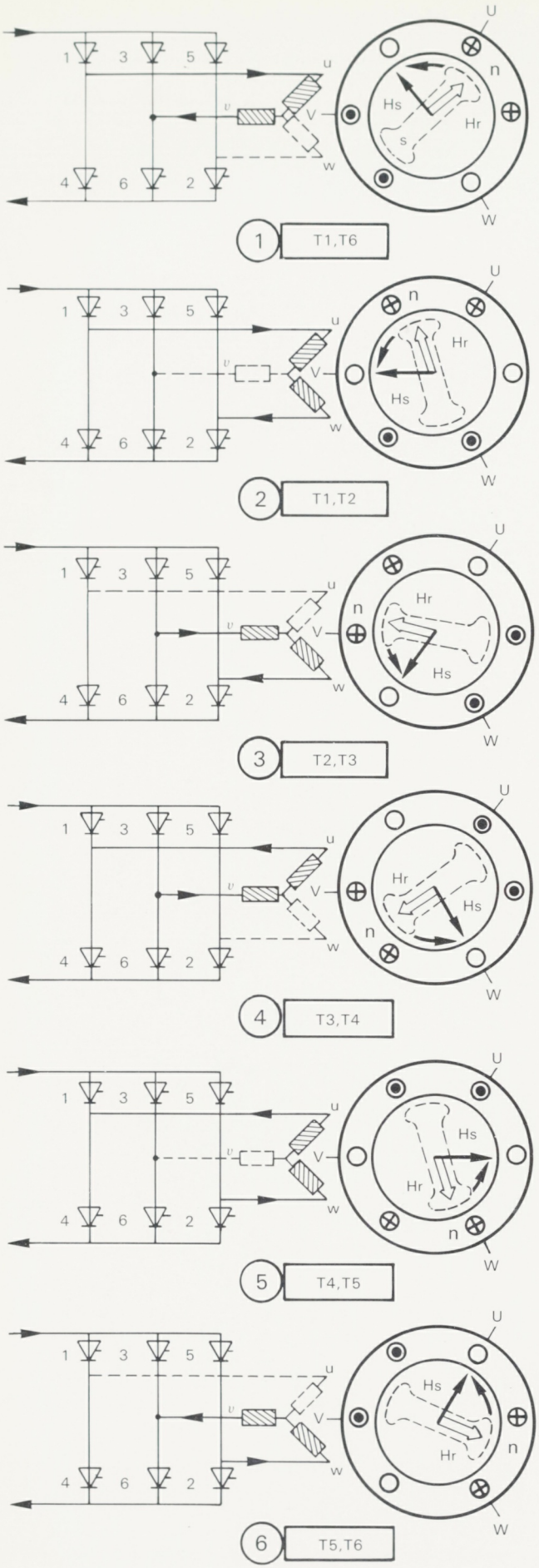


Figure D5 Synchronous motor powered by an Autosynchronous inverter

CORRIGENDA

1. Page 5 Paragraph 5.1.4. Last sentence should read – 'Optical fibres are also insensitive to electrical interference.'

2. Page 9 Figure 8. The floating 'n' on the stator signifying the north pole, should be on the rotor as indicated on amended Figure D5.

3. Page 13 Paragraph 6.4.41. Recent cases have shown that air-break type interrupters are currently being favoured for the main propulsion motor circuit breakers at high voltage.

4. Page 14 Paragraph 6.4.4.2. The MICOPERI crane barge has air-break interrupters not vacuum as stated.

5. Page 18 Figure 17. The interconnector between the changeover switches has been ommited see amended Figure D6.

6. Page 21 Paragraph 8.5. 10th line. Delete 'vacuum' and insert 'air-break'.

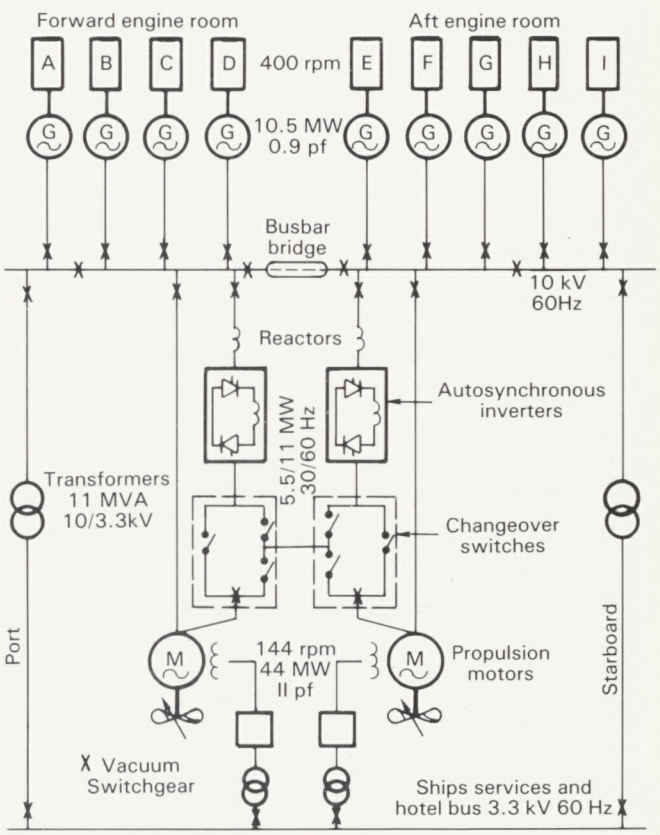
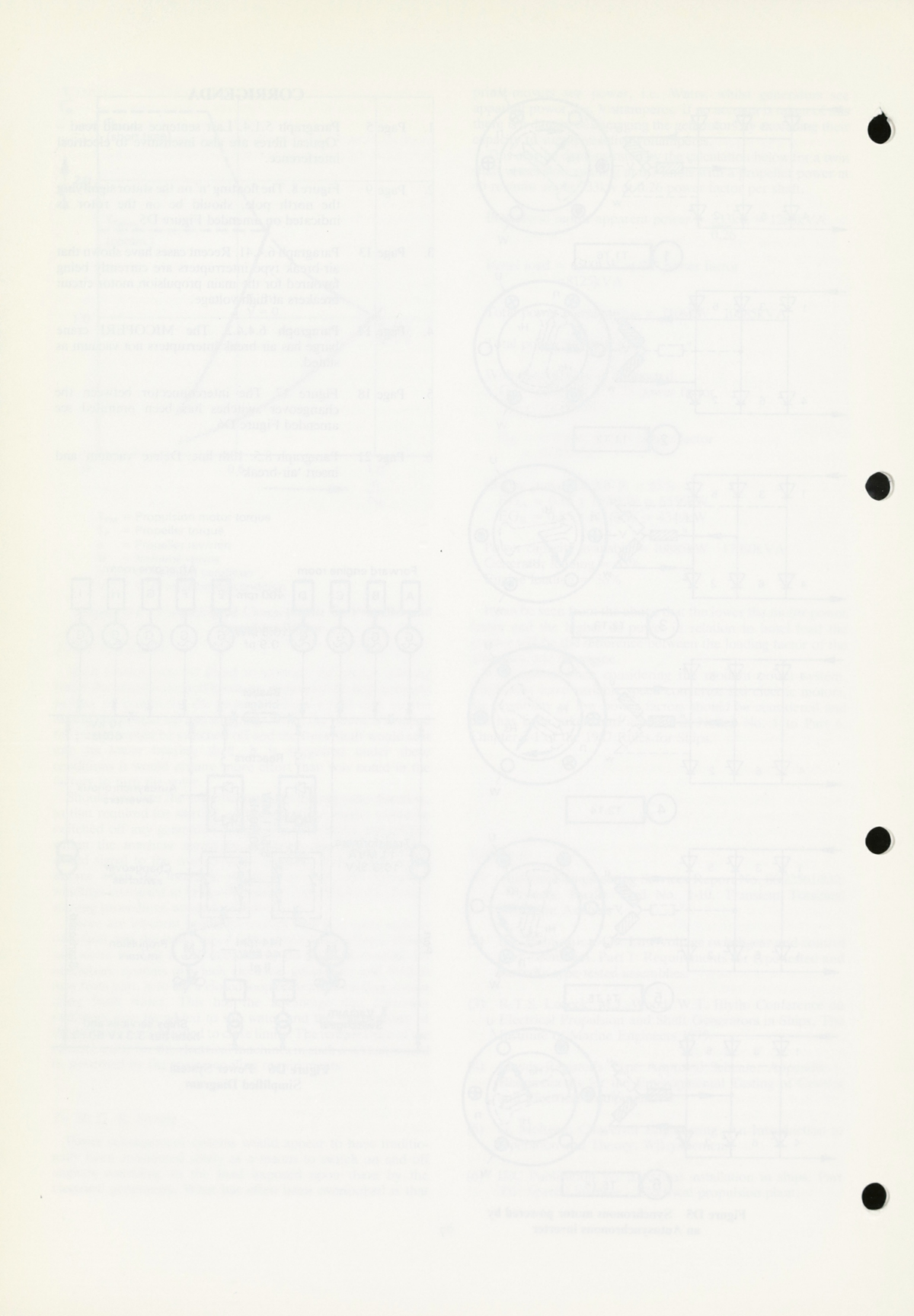


Figure D6 Power System – Simplified Diagram



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Lloyd's Register Technical Association

CARGO SHIP SAFETY EQUIPMENT AND RADIO AND PASSENGER SHIP SAFETY SURVEYS AND CERTIFICATION

C. H. A. Marshall and J. V. Rugg

Paper No. 3. Session 1987—88

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Hon. Sec. R. V. Pomeroy
71 Fenchurch Street, London, EC3M 4BS

CARGO SHIP SAFETY EQUIPMENT AND RADIO AND PASSENGER SHIP SAFETY SURVEYS AND CERTIFICATION

by

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TABLE OF CONTENTS

PART I

1.1 INTRODUCTION
1.2 HISTORICAL BACKGROUND
1.3 GENERAL PROCEDURES
1.4 INITIAL SURVEYS ON CARGO SHIPS
1.5 INITIAL SURVEYS ON PASSENGER SHIPS
1.6 SURVEYS ON EXISTING CARGO SHIPS
1.7 SURVEYS ON EXISTING PASSENGER SHIPS
1.8 CHANGE OF FLAG SURVEYS ON CARGO SHIPS
1.9 CHANGE OF FLAG SURVEYS ON PASSENGER SHIPS
1.10 ISSUE OF CARGO SHIP SHORT TERM CERTIFICATES
1.11 PASSENGER SHIP SAFETY CERTIFICATES OF RESTRICTED VALIDITY
1.12 EXTENSION OF CARGO SHIP SAFETY EQUIPMENT CERTIFICATES
1.13 PASSENGER SHIP SAFETY CERTIFICATE EXTENSIONS
1.14 COMPUTER BASED REPORTING
1.15 PORT STATE INSPECTIONS

PART II

II-1 REQUIREMENTS FOR NEW AND EXISTING CARGO SHIPS AND GUIDANCE ON COMPLETION OF SE1
II-2 GUIDANCE ON COMPLETION OF PASSENGER SHIP SE1

PART III

CONVENTION RADIO REQUIREMENTS

APPENDICES

A SURVEY & TEST PROCEDURES FOR FIRE MAIN
B SURVEY & TEST PROCEDURES FOR PORTABLE FIRE EXTINGUISHERS
C SURVEY & TEST PROCEDURES FOR BREATHING APPARATUS
D SURVEY & TEST PROCEDURES FOR CO_2 & HALON SYSTEMS
E SURVEY & TEST PROCEDURES FOR FOAM SYSTEMS
F SURVEY & TEST PROCEDURES FOR SPRINKLER SYSTEMS
G SURVEY & TEST PROCEDURES FOR INERT GAS SYSTEMS

ANNEXES

I 1978 PROTOCOL 1981 AND 1983 AMENDMENTS TO SOLAS 1974

II SAFETY GUIDELINES FOR CARGO SHIPS OF LESS THAN CONVENTION SIZE AND ASSOCIATED STATEMENTS

III PASSENGER SHIP SAFETY, INITIAL SURVEY PLANS REQUIRED

PART I

I.1 INTRODUCTION

The object of this paper is to provide a comprehensive guidance document and ready reference for Surveyors involved in cargo and passenger ships safety surveys.

The previous two classic papers on this subject were by Messrs MacMillan and Smart some 29 and 16 years ago respectively. Mr. Smart's paper was presented during the 1970-71 session of the L.R.T.A. and addressed the requirements of the 1960 SOLAS Convention.

Since publication of the latter the 1974 SOLAS Convention together with the 1978 Protocol thereto and the 1981 Amendments and 1983 Amendments thereto have all entered into force, as have the International Regulations for the Prevention of Collisions at Sea, 1972.

Disasters at sea are newsworthy items receiving widespread, worldwide coverage in the media. Every major incident or series of casualties stimulates public and governmental pressure for improved safety at sea. Loss of life and environmental pollution are emotive factors in the formulation of new and increasingly stringent safety legislation.

A ship is a self-contained unit which must be properly equipped to maintain life onboard. The hull must be strong enough to bear the stresses imposed by cargoes, the sea and adverse weather. It must provide a stable platform in all conditions, and watertight integrity must be maintained. Navigation needs to be accurate and provision made to combat hazards such as fire and flooding. Communications need to be provided to call for help when necessary. When all else fails means must be available for the crew to abandon ship and to survive in a hostile sea until located and rescued.

Safety may be defined simply as freedom from danger or risk. If the question of safety alone was involved then the achievement of standards of the highest order would be comparatively easy. However, economic aspects of construction, equipment and operation also have to be taken into account. The difficulties involved become apparent when trying to establish an equitable balance between safety and the cost of sea transport. The major cause of shipping losses has been, and still is considered to be human error. Safety regulations, therefore, attempt to anticipate such human failing as far as is practicably feasible.

The efforts of those engaged in framing safety regulations are conditioned by the sum of knowledge available at that time, by prevailing circumstances reflected in the types of existing ships and the cargoes they carry, by casualty statistics, by the progress of science and technology, and by the difficulty of forecasting developments beyond a relatively near future.

The training of ships' officers and crews, the navigation of ships, the proper marking of coasts, channels, natural and other hazards and the availability of reliable navigational aids, radio communications, charts and weather information, although vital factors in the equation of safety at sea, have little direct influence on the design of ships. On the other hand, strength, stability, weathertight integrity, the capability to survive external damage or flooding, the reduction of the risk of fire and provision of means to fight it, and the provision of lifesaving equipment are the basic elements of safety which do influence the design of ships.

I.2 HISTORICAL BACKGROUND

As long ago as 1854 the United Kingdom Merchant Shipping Act required all British Ships and all foreign flag ships carrying passengers between ports in the United Kingdom to carry "boats duly supplied with all requisites for use". In addition, on ships carrying more than 10 passengers, a "lifeboat" was to be carried unless one of the previously mentioned boats was "rendered buoyant after the manner of a lifeboat". However, the number of boats required under this Act was dependent on tonnage and not the complement of the ship. It should be noted that the regulations only applied to ships carrying passengers and it was not until 1882 that the loss of 548 British ships and 3000 lives prompted the introduction of the first U.K. legislation to preserve the freeboard of ships by restricting cargo loading to the famous "Plimsoll Line", thus addressing some aspects of the safety of all persons on ships at sea.

Later U.K. Acts concerning the provision of life-saving equipment increased the number of boats to be carried although collapsible canvas boats and boats without buoyancy were still permitted. The onus was put on the Owner and Master of the ship to see "that his ship is provided with such boats, lifejackets and other appliances for saving life at sea, having regard to the nature of the service on which the ship is employed, and the avoidance of undue encumberance on deck as are best adapted for securing the safety of crew and passengers".

The U.K. Regulations of 1902 gave a schedule of the minimum number of boats to be carried on passenger ships and required that the capacity of these boats be supplemented by additional boats, collapsible boats or liferafts to accommodate all onboard. Lifebelts for all on board were also compulsory. However the number of additional boats was permitted to be reduced if the subdivision of the ship was to the satisfaction of the Board of Trade. Thus at the time of the Titanic disaster in 1912 it was unfortunately not necessary to have boats for all onboard.

This tragedy lead to the convening of the 1914 International Conference which dealt with the safety of navigation for all merchant ships and, for passenger ships with provision for watertight and fire resisting bulkheads, fire prevention, fire fighting and lifesaving appliances. This convention did not enter into force due to the outbreak of the 1914-18 war.

In 1929 a further conference, attended by 18 countries, was held in London and a new SOLAS Convention was produced. This was basically an updated version of the 1914 agreement but to which was also annexed the revised regulations for Preventing Collisions at Sea. This was later superseded by the 1948 SOLAS Convention which upgraded the watertight subdivision standards to ensure that passenger ships would stay afloat after sustaining damage as specified by the Convention. Cross connection of spaces was introduced to reduce the angle of heel due to assymetrical flooding. Three alternative methods of subdivision by means of fire resistant bulkheads were introduced together with a requirement for the enclosure of main stairways. The International Safety Equipment Certificate for cargo ships of 500 gross tons and above was also introduced at this time.

Prior to 1948, International Conferences on Safety at Sea had been convened at the invitation of the Government of the United Kingdom. Then a significant event occurred. The Inter-Governmental Maritime Consultative Organisation (IMCO), now known as the International Maritime Organisation (IMO), was established by a Convention promoted by the United Nations at Geneva in 1948 and came into being in 1958. For the first time there existed an international organisation which could keep safety requirements under continuous review and address new problems as they occurred instead of being dependent on the one Government.

The first SOLAS Convention produced by this new body was

prepared in 1960. More rigid standards of subdivision were defined and various passenger ship requirements were further revised and provision was made for the substitution of lifeboats by liferafts in certain instances. The 1960 SOLAS Convention also required all cargo ships of 500 gross tons and upwards to have a Safety Construction Certificate.

A significant number of important changes to SOLAS '60 were made in the 1974 SOLAS Convention, particularly with respect to structural fire protection on passenger ships and radio and safety of navigation requirements in general. Subsequently, as a result of significant tanker losses due to explosions, prior to entry into force of SOLAS '74, it was necessary for IMO to adopt the 1978 Protocol to SOLAS '74. This introduced requirements considered necessary to improve the safety of tankers but also included requirements for shipborne navigational equipment to be carried in all ships. The 1978 PROTOCOL also contained requirements for annual safety equipment surveys on all dry cargo ships and on tankers less than ten years old and intermediate safety equipment surveys for tankers of ten years of age and over.

SOLAS '74 has been amended twice since entry into force, in 1981 and 1983. The 1981 Amendments contain a complete revision of Chapters II-1 and II-2. Chapter II-1 relates to subdivision and damage stability of passenger ships together with bulkhead, bilge pumping, machinery and electrical installation requirements on both passenger and cargo ships. Chapter II-2 addresses fire protection, detection and extinction arrangements and introduced major revisions with respect to cargo ships. Chapter III was the subject of some editorial changes whilst substantial amendments to the basic SOLAS '74 document were made to Chapters IV and V. The 1983 Amendments consist of a complete revision to Chapter III, Lifesaving Appliances, Chapter VIII, Carriage of Dangerous Goods, and minor amendments to Chapters II and IV.

The SOLAS regulations addressed by this paper are those of the 1974 Convention, the 1978 Protocol thereto and the 1981 and 1983 Amendments thereto. The 1972 International Regulations for the Prevention of Collisions at Sea will also be considered.

Table 1

Convention	Entry into force
1948 SOLAS	19th November 1952
1960 SOLAS	27th May 1965
1966-73 Amendments to SOLAS 1960 and Supplements Parts G & H	–
1974 SOLAS	25th May 1980
1978 Protocol to SOLAS 1974	1st May 1981
1981 Amendments to SOLAS 1974	1st September 1984
1983 Amendments to SOLAS 1974	1st July 1986

Chronological List of the Conventions, Amendments and Supplements

I.3 GENERAL PROCEDURES

Cargo ship safety equipment and safety radio surveys and passenger ship safety surveys may only be held on ships, the flag state of which has authorised Lloyd's Register to carry out the survey and issue the relevant certificates on its behalf.

The Society's Headquarters provides guidance to Outport Surveyors either by general or particular instructions to carry out the survey concerned. Only in exceptional circumstances and with the prior approval of Headquarters may persons other than exclusive Surveyors to Lloyd's Register carry out such statutory surveys.

Ships built prior to the entry into force of the Convention currently applied by the flag state are certified as existing ships under the terms of the later Convention e.g. a ship built to comply with SOLAS 1948 or SOLAS 1960 built before 25th May 1980 would be issued with a 1974 certificate as an existing ship of a flag state which is a signatory to SOLAS 1974.

Various countries having accepted a convention will then publish their own National Regulations which may have differing and perhaps more rigorous requirements than those applied by other flag states, or the basic SOLAS Convention.

The regulations of SOLAS 1974, require that all cargo ships of 500 Gross Tons (G.T.) and upwards engaged on International voyages, be provided with a Cargo Ship Safety Equipment Certificate valid two years, that Cargo Ships of 300 GT and upwards but less than 1600 GT be provided with a Radiotelephony Certificate and that Cargo Ships of 1600 GT and upwards be provided with a Radiotelegraphy Certificate. Safety Radio Certificates have a period of validity of one year. These certificates are required in addition to the Safety Construction Certificate required to be issued to cargo ships of 500 GT and upwards.

All passenger ships are required to have a Passenger Ship Safety Certificate. This Certificate, which has a maximum validity of one year, embodies the equivalent of the Cargo Ship Safety Equipment, Safety Radio and Safety Construction Certificates in one document. Thus a separate Safety Construction Certificate is not required for passenger ships.

The SOLAS 1974 requirements do not, unless expressly provided otherwise, apply to:-

(a) Ships of war and troopships;
(b) Cargo ships of less than 500 gross tons;
(c) Ships not propelled by mechanical means;
(d) Wooden ships of primitive build;
(e) Pleasure yachts not engaged in trade;
(f) Fishing vessels.

The items required to be verified fitted and found in efficient working order prior to the issue of a Cargo Ship Safety Equipment certificate can be grouped under the headings of:-

(a) Fire detection and extinction arrangements
(b) Life saving appliances:-
    (i) Survival craft
    (ii) Personal life saving appliances
(c) Display of fire control and lifesaving appliance plans
(d) Nautical publications, training manuals, drills and tests etc
(e) Navigational equipment
(f) Pilot boarding arrangements
(g) Lights, shapes and means of making sound signals as required by the collision regulations in force. [presently the 1972 Regulations for the Prevention of Collisions at Sea].

and for Passenger ships, in addition to the above:-

(h) Radio equipment onboard and in survival craft
(i) Construction:-
    (i) Ships structure including structural fire protection
    (ii) External examination of ship's bottom
    (iii) Boilers, pressure vessels and their fittings
    (iv) Main and auxiliary machinery
    (v) Electrical installation
(j) Damage control facilities
    (i) Watertight doors
    (ii) Bulkhead valves
    (iii) Cross flooding devices
    (iv) Downflooding arrangements
    (v) Bilge pumping and piping
    (vi) Swimming pool dumping arrangements
(k) External watertight integrity
    (i) Side shell doors below bulkhead deck
    (ii) Side scuttles below bulkhead deck
    (iii) Scuppers and overboard discharges
    (iv) Short sounding pipes
(l) Weathertight Integrity
    (i) Air pipes and their closing appliances
    (ii) Ventilators and their closing appliances
    (iii) Weathertight doors
    (iv) Hatchcovers

(v) Windows and sidecuttles
(vi) Sounding pipes

(m) Documentation
(i) Fire control, damage control and life saving appliances plans displayed
(ii) Muster lists displayed
(iii) Approved Loading Manuals and stability information onboard

(n) Drills, alarms and signals
(i) Fire and general alarms
(ii) Ship's whistle
(iii) Public address and 'crew only' address
(iv) Fire drill
(v) Boat drill

A number of the above items, may well be dealt with in conjunction with the annual loadline/classification survey. Should this survey not be harmonized with the passenger ship safety renewal survey, or the applicable cargo ship safety equipment survey, surveyors should be satisfied that these common items remain efficient. The items in section (i), with the exception of item (ii) are generally covered in the normal classification C.S.H. and C.S.M. cycles. If a passenger ship is not on a continuous survey cycle then each passenger ship safety renewal survey would virtually become a special survey.

External examination of the ships bottom is permissible on alternate years with the consent of the flag state by holding an underwater inspection of the ship's bottom, in lieu of dry docking. If this inspection is also for class it should be carried out by a qualified diver in accordance with approved classification requirements.

A flag state administration may exempt any ship flying its flag from any of the provisions of Chapters II-1, II-2, III and IV of the SOLAS Convention if it embodies features of a novel kind. It is usual for a copy of the certificate issued in respect of an Exemption from Convention requirements to be attached to the applicable Convention Certificate held on board the vessel. It is also a requirement that the Administration issuing an Exemption certificate should forward a copy to the I.M.O. for the information of interested third parties, including all Governments who are Contracting parties to the Convention. Under the terms of the SOLAS Convention equivalent arrangements are to be acceptable to any Administration.

I.4 INITIAL SURVEYS ON CARGO SHIPS

It is important that a correctly completed Request 1 is forwarded to H.Q. at an early stage in order that the flag state authorisation and applicable regulations may be confirmed. In cases where the Society is not authorised to deal with safety equipment surveys and certification, any request should be referred to H.Q. for advice on action to be taken.

Plans which indicate the life-saving and fire-fighting arrangements together with plans of the arrangement of navigation lights and sound signals are to be forwarded to H.Q., in triplicate, at an early date for approval if not being dealt with by local Plan Approval Offices.

Lifeboats and davits are to be built under survey in accordance with approved plans. If plans of the lifeboats have not previously been approved in H.Q., or confirmed acceptable by virtue of approval by a recognised authority, then detailed drawings of the lines, general arrangement, construction arrangement, lifting hooks and attachments, motor seating and buoyancy calculations are to be submitted for approval. Detail plans of the davit construction and stress calculations are also to be submitted for approval.

A copy of any plans of life-saving appliances, navigation light arrangements, lifeboats and davits which have been locally approved, should be forwarded to H.Q. for record purposes as soon as possible.

Equipment manufactured and approved by a signatory country as being in accordance with, or equivalent to, the requirements of a particular Convention is generally accepted by other signatory states to the same Convention.

I.5 INITIAL SURVEYS ON PASSENGER SHIPS

Passenger ship safety surveys on new construction are co-ordinated by the I.C.D. Passenger Ship Safety Section in H.Q. Plans as per the list in Annex III should be forwarded for approval.

It is particularly important that a general arrangement, lines plan and/or offsets, hydrostatic data, preliminary loading manual and arrangement of escapes are forwarded at the earliest opportunity. It is often advantageous for a shipyard to request the Society to examine these particular plans before the contract is signed. The location of subdivision bulkheads and proposed internal arrangements can then be examined for compliance with the relevant criteria for damage stability. Stairway enclosures and escape routes can also be examined to ensure their satisfactory location. The importance of this early investigation cannot be over emphasized since later rectification, if necessary for compliance, may be extremely difficult and costly.

The bulk of the safety survey will be the responsibility of local surveyors who will receive guidance from H.Q. supplemented by visits of a specialist surveyor from the Passenger Ship Safety Section. Assistance from H.Q. is always given for the inclining experiment, final inspections and drills prior to the issue of the Passenger Ship Safety Certificate.

I.6 SURVEYS ON EXISTING CARGO SHIPS

When requested to undertake a survey for the renewal of a Safety Equipment Certificate the first consideration is to ensure that Lloyd's Register is authorised to carry out the work. Particulars of the expired certificate should be ascertained, whether full or short-term and by whom issued, in order to determine the extent of survey required. This could be any of the following:-

(a) Renewal of a full-term certificate issued by Lloyd's Register or a Cert. SEST issued in the form of an extension to the full term Certificate. In this case a complete renewal survey is necessary.

(b) Renewal of a full-term certificate issued by an Authority other than Lloyd's Register. For this a complete renewal survey is necessary, together with the preparation of a complete revised Rpt. SE1.

(c) Renewal of a Cert. SEST issued by one of the Society's Surveyors, other than that issued in the form of an extension. This should indicate that a survey has been commenced or advanced previously. Any outstanding items shown on the back of the Cert. SEST should be dealt with before issuing a further certificate. If facilities are not available for dealing with the outstanding items, permission to issue a further Cert. SEST should be sought from H.Q. stating the Owner's proposals for completion of the survey. The ICD microfiche will indicate service/repair facilities at subsequent intended ports of call.

(d) Where in respect of a vessel of 500 G.T. or more, a Rpt. 10 has been issued previously, a Cert. SEST may not be issued until all the items mentioned thereon have been satisfactorily dealt with.

If there are any doubts with regard to the procedure to be followed after the I.C.P.M., associated circulars, ICD/ICL's and any H.Q. Instructions have been consulted, H.Q. should be contacted immediately.

I.7 SURVEYS ON EXISTING PASSENGER SHIPS

Outports should advise H.Q. immediately a request is received to renew an expired Passenger Ship Safety Certificate. Full instructions for the survey will then be forwarded to the outport together with the original and one certified copy of the Passenger Ship Safety Certificate. Both of these Certificates

should be placed onboard on satisfactory completion of the survey. Ports under the jurisdiction of New York should contact that Office in the first instance.

I.8 CHANGE OF FLAG SURVEYS ON CARGO SHIPS

When a change of flag takes place in respect of a vessel classed with the Society and a request is received to issue Statutory certificates on behalf of the new flag State Administration, the procedure is as follows.

The International Conventions Procedure Microfiche (I.C.P.M.) should be consulted to determine if Lloyd's Register is authorised to act on behalf of the Administration. If Lloyd's Register is not authorised to deal with the survey and certification. H.Q. should be contacted immediately with details of the request. In those cases where the Society is authorised, the current position of the Safety Equipment or Radio Certificate should next be determined from the monthly listing microfiche or the computer generated proforma as appropriate.

On classed vessels, where Lloyd's Register has not issued the existing certificate, or on vessels changing to LR Class at time of change of flag, it is necessary to hold a complete renewal survey and prepare a copy of the Rpt. SE1 "Record of Safety Equipment" and Rpt. SE2 for submission to H.Q. unless advised to the contrary. It should be borne in mind that the vessel may have previously changed flag, and perhaps class, consequently some information of use may be held in H.Q. and could be made available.

For a vessel in possession of a Safety Equipment Certificate issued by Lloyds Register, the following is the recommended procedure unless advised otherwise by H.Q.:-

(a) If there is less than nine months validity remaining on the existing certificate, a full renewal survey should be requested.

(b) If the 1978 Protocol to SOLAS 1974 is applicable, and the time of the request falls within the Range Dates (the six months envelope allowed by the Protocol) an Annual or Intermediate Survey of Safety Equipment must be held if it has not been held previously within those dates. When the Annual or Intermediate Survey has previously been held within the range dates it will be sufficient for a satisfactory General Examination of Safety Equipment to be held. There is, of course, no objection to a full Renewal Survey being held at the Owners' request. Such a request may be received in those cases where it is to the Owners' advantage to harmonise future safety equipment survey dates with due dates of survey in respect of other statutory certificates.

(c) In those cases where the vessel will fly the flag of a State which has not signed the Protocol to SOLAS 1974, the procedure outlined in paragraph (b) above should be used as a guide.

(d) In All other cases, i.e., where the request is received fifteen months or more before the expiry date of the existing full-term certificate, it will be sufficient to hold a satisfactory General Examination unless the owner requires that a full renewal survey is held.

Great care should be taken at change of flag surveys to ensure that any system operating instructions, training manuals, on board maintenance manuals, steering gear operating/change over instructions etc., are in a language understood by the crew.

As a minimum requirement at the change of flag survey, it must be ensured that any instructions related to the operation of the fixed fire extinguishing systems, steering gear and any associated equipment are understood by the crew or that the crew are able to demonstrate their ability to operate the system and equipment before any SEST is issued. If this is not the case H.Q. should be consulted.

It is important to ensure that lifeboats, lifebuoys and any rigid liferafts fitted are correctly marked with name and port of registry of the ship to which they belong. It should also be verified that the markings on inflatable liferaft containers are as required by the SOLAS Convention and that the applicable service certificate is valid.

In all cases the Owner should be made fully aware of exactly what degree of Safety Equipment survey has been dealt with and when his next survey, either Annual, Intermediate or Renewal, will become due and the validity of certificate he can expect. Cases are on record where an Owner has anticipated receiving a full-term two-year Safety Equipment Certificate after a change of flag survey which was not a full renewal survey. This obviously causes unnecessary embarrassment to all concerned.

I.9 CHANGE OF FLAG SURVEYS ON PASSENGER SHIPS

With Passenger Ships it will again be necessary to advise H.Q. (New York if applicable) of any change of flag cases in order that instructions and the correct certificate may be forwarded. In cases where the change of flag is between states, for both of which Lloyd's Register is authorised to act, the survey will generally be exclusively dealt with by the outport concerned. Where the Society was not authorised by the previous flag and has not been responsible for any certification previously issued to the ship, this initial survey will be held by the outport in conjunction with a specialist surveyor from H.Q. In these cases it may also be necessary to request various plans and manuals from the owner in order to complete the necessary H.Q. records.

I.10 ISSUE OF CARGO SHIP SHORT-TERM CERTIFICATES

It is stressed that safety equipment surveys should, whenever possible, be completed in their entirety at one time. Far too many conditional Short-Term Certificates are currently being issued. Only on those occasions where the required services or replacement equipment are not available locally should a conditional Short-Term Certificate be issued. After discussion with the Owners, the validity of the SEST should be adequate to allow the vessel to reach the next exclusive LR Surveyor Port where facilities exist to deal with the outstanding items. In such cases, the certificate should be clearly marked "CONDITIONAL" and also endorsed in respect of those items which remain outstanding for completion of the survey.

I.11 PASSENGER SHIP SAFETY CERTIFICATES OF RESTRICTED VALIDITY

There is no short term Passenger Ship Safety Certificate. In the unlikely event that the survey has not been completed satisfactorily a certificate of restricted validity may possibly be issued but only with the agreement of H.Q.

I.12 EXTENSION OF CARGO SHIP SAFETY EQUIPMENT CERTIFICATES

A Safety Equipment Certificate is issued for a period not exceeding two years, with any Annual or Intermediate survey being held as necessary. It is expected to be renewed on or by the expiry date. It may, however, be extended for a period of grace of up to one month from the date of expiry.

If a ship, at the time when it's certificate expires, is not in a port of the country in which it is registered, or is unable to undergo survey either due to the lack of facilities or other justifiable reason, the certificate may be extended for a period up to a maximum of five months. Such an extension may be granted, only when it appears reasonable and proper, for the purpose of allowing the ship to complete its voyage to the country in which it is registered, or is to be surveyed, and where a safety equipment renewal survey must be carried out upon arrival.

Surveyors are authorised to extend full-term certificates which have been issued by Lloyd's Register, for periods up to one month, without reference to H.Q. provided they are satis-

fied that the condition and efficiency of the equipment warrants such an extension. Procedural details are given in the ICPM. Any application for an extension of a certificate for a period longer than one month is to be referred to H.Q. or, in the case of ships registered in Liberia, to New York Office if more expeditious.

If the extension is recommended, and the equipment and appliances are generally examined and found serviceable, the certificate, except in the case of Liberian ships, is to be endorsed "This certificate is extended in accordance with the provisions of the Regulations for a period of grace and will continue to remain in force until .... day .... month .... year". For Liberian ships, the full term certificate is to be withdrawn and a Cert. SEST issued to the ship bearing the statement "This certificate is issued in the form of an extension to the previous document expiring on the .... day .... month .... year, in accordance with the provisions of the Regulations".

I.13 PASSENGER SHIP SAFETY CERTIFICATE EXTENSIONS

Any request for the extension of a Passenger Ship Safety Certificate should immediately be forwarded to H.Q.

I.14 COMPUTER BASED REPORTING

With the introduction of the computer based system of reporting, surveyors are reminded that any items outstanding for completion of a survey are to be reported, not those dealt with for commencement of a survey. In order to assist H.Q. I.C.D. staff the narrative section should always include the following statement:-

"The short term certificate (insert SEST or SRST) now issued replaces the certificate (insert full term or short term) issued at (insert place) on (insert date)".

and if applicable:-

"The short term certificate now issued is endorsed in respect of the items shown below as outstanding for completion of the survey".

It therefore follows that should time preclude any worthwhile portion of the survey being held, the matter should be discussed with the Owner with a view to extending the validity of the existing certificate as permitted by Reg 14 (c) of Chapter I of SOLAS 1974. It should be drawn to the Owner's attention that should the vessel reach the intended port of survey before the expiry of any extension, the vessel would not be permitted to clear port on the unexpired period of the extension without the required survey being held [Reg 14 (d) of Chapter I of SOLAS 1974 refers].

I.15 PORT STATE INSPECTIONS

National Authorities may inspect any vessel in their ports at any time. During the period July 1984 to June 1985 the European Countries which are signatories to the 'Memorandum of Understanding on Port State Control' carried out over 10,000 inspections on more than 7600 vessels from over 100 different flag states. The inspections resulted in more than 400 vessels being detained or delayed due to serious defects or deficiences. It is usual for the Port State Inspector to involve the local representative of the organisation responsible for the issue of the certificate to which the alleged deficiencies relate. When an L.R. Office is advised of a detention due to alleged deficiencies, on a vessel to which the Society has issued the applicable certificate, the following procedure should be followed:-

(i) Advise H.Q. immediately.

(ii) Arrange to receive a copy of the detention report, for submission to H.Q.

(iii) Ensure that when the report is submitted, H.Q. is also advised of:-

(a) the final list of deficiencies (sometimes reduced from the total initially alleged after discussion with Port State Inspector).

(b) the deficiencies dealt with before the vessel cleared; and, if applicable.

(c) any deficiencies allowed by the port state to remain outstanding and arrangements made for completion at subsequent port/ports of call. It should also be confirmed that the L.R. Surveyor/Surveyors at the subsequent port/ports concerned have been alerted to the situation.

After a detention report is issued, the Port State authority advise I.M.O. of the detention. I.M.O. then advise the flag state of the ship, who in turn contact the authority/organisation responsible for the issue of the applicable certificate in order to obtain an explanation prior to the flag state responding to I.M.O. It follows therefore that details related to repairs/renewals or replacement, service and expiry dates of equipment, **MUST** be adequately recorded at the time of Renewal, Annual or Intermediate surveys of Safety Equipment of Radio Renewal Surveys and be fully reported in the computer based Report narrative section in order that H.Q. will be in a position to respond promptly to any such enquiry.

PART II

II.1 REQUIREMENTS ON NEW AND EXISTING CARGO SHIPS AND GUIDANCE ON COMPLETION OF SE1

The revised Record of Safety Equipment Rpt. 2029 (5/87) SE1, is to be completed for all new ships and for all existing ships undergoing initial surveys. (First by Lloyd's Register).

Careful preparation of the Rpt. SE1 will obviate the necessity for the Surveyor to be faced with the difficult task of answering queries some time after a survey was held. It is the Surveyor's duty to ensure that any deficiencies are made good and the equipment is in accordance with Regulations and not merely to report what is onboard.

A copy of the Rpt. SE1 will eventually be placed onboard the ship for the guidance of the Surveyors at subsequent surveys and remarks as to the condition of the equipment, comments such as "To be supplied" or "Not examined" and dates of service or expiry, should not be included on this form. Reports must be factual and opinions or statements liable to misinterpretation should not be used.

Every effort must be made to complete the Rpt. SE1 of an existing ship in its entirety in one operation in order that the case may be examined in H.Q. and a Safety Equipment Certificate issued as soon as possible. Receipt of a part completed Rpt. SE1 only leads to unnecessary correspondence between H.Q. the Owners and the Surveyors and causes much delay and inconvenience.

The following guidance on the completion of a Rpt. SE1 is set out in the same sequence as the main headings appear in the Report and numbered for easy reference. It will be noted that space has been made available at the end of the Rpt. SE1 to facilitate the inclusion of any special features or "overflow" information for which space was not available on earlier pages.

001 Record of Approved Cargo Ship Safety Equipment

A copy of this report should not be left onboard by the Surveyor carrying out the initial survey. In the first instance, the completed report should be forward to H.Q. in order that the details may be checked and, if all is in order, a copy is then issued to the Owners for onward transmission to the ship.

002 Main Particulars

If any particulars are not known the space should be left blank. In some instances change of registration also means

Lloyd's Register of Shipping

001 **RECORD OF APPROVED CARGO SHIP SAFETY EQUIPMENT**

TO MEET THE PROVISIONS OF THE INTERNATIONAL CONVENTION FOR THE SAFETY OF LIFE AT SEA, 1974, AND AMENDMENTS THERETO.

THIS RECORD MUST BE KEPT ON BOARD AT ALL TIMES AND BE AVAILABLE FOR INSPECTION BY A NOMINATED SURVEYOR OR RECOGNISED ORGANISATION.

NAME OF SHIP	SIGNAL LETTERS	NATIONALITY AND PORT OF REGISTRY	GROSS TONNAGE	DATE KEEL LAID†

PREVIOUS NAME AND NATIONALITY	NAMES OF ANY KNOWN SISTERSHIPS

002

BUILDERS	YARD NUMBER	L.R. NUMBER

CLASS	TYPE OF SHIP

0·96 × THE LENGTH ON A WATERLINE AT 85% OF THE LEAST MOULDED DEPTH FROM TOP OF KEEL OR THE LENGTH FROM THE FORESIDE OF THE STEM TO THE AXIS OF THE RUDDER STOCK ON THAT WATERLINE, WHICHEVER IS THE GREATER	

NAME OF OWNERS, MANAGERS OR MANAGING AGENTS	REGISTERED LENGTH	OVERALL LENGTH
	B.P. LENGTH	MAXIMUM BREADTH
ADDRESS	TYPE OF MACHINERY AND OUTPUT (kW)	AUXILIARIES AND OUTPUT (kW)
	MAIN BOILERS—NUMBER AND TYPE	AUXILIARY BOILERS—NUMBER AND TYPE

003

NUMBER	THE TOTAL NUMBER OF PERSONS PROVIDED FOR BY LIFE SAVING APPLIANCES IS		AND NO MORE VIZ.
	LIFEBOATS ON PORTSIDE CAPABLE OF ACCOMMODATING	PERSONS	*SELF-RIGHTING/PARTIALLY/TOTALLY ENCLOSED/WITH SELF-CONTAINED AIR SUPPORT SYSTEM/FIRE PROTECTED/OPEN
	LIFEBOATS ON STARBOARD SIDE CAPABLE OF ACCOMMODATING	PERSONS	*SELF-RIGHTING/PARTIALLY/TOTALLY ENCLOSED/WITH SELF-CONTAINED AIR SUPPORT SYSTEM/FIRE PROTECTED/OPEN
	MOTOR LIFEBOATS (INCLUDED IN THE TOTAL LIFEBOATS SHOWN ABOVE).		
	FREE-FALL LIFEBOATS CAPABLE OF ACCOMMODATING	PERSONS	*SELF-RIGHTING/WITH SELF-CONTAINED AIR SUPPORT SYSTEM/FIRE-PROTECTED
	RESCUE BOATS (*INCLUDED/NOT INCLUDED IN THE TOTAL LIFEBOATS SHOWN ABOVE), CAPABLE OF ACCOMMODATING	PERSONS	
	LIFERAFTS FOR WHICH APPROVED LAUNCHING APPLIANCES ARE REQUIRED CAPABLE OF ACCOMMODATING	PERSONS	
	LIFERAFTS FOR WHICH APPROVED LAUNCHING APPLIANCES ARE NOT REQUIRED CAPABLE OF ACCOMMODATING	PERSONS	
	LIFERAFTS STOWED FORWARD/AFT CAPABLE OF ACCOMMODATING	PERSONS	
	LIFEBUOYS		
	LIFEJACKETS		
	IMMERSION SUITS		
	THERMAL PROTECTIVE AIDS		

004

SHIP DEFINITION	APPLICABLE TO NEW SHIPS FROM
*NEW/EXISTING SHIP UNDER THE PROVISIONS OF SOLAS 74	25 MAY 1980
*NEW/EXISTING SHIP UNDER THE PROVISIONS OF THE 1981 AMENDMENTS TO SOLAS 74	1 SEPTEMBER 1984
*NEW/EXISTING SHIP UNDER THE PROVISIONS OF THE 1983 AMENDMENTS TO SOLAS 74	1 JULY 1986

†NOTE: IT WILL BE SUFFICIENT TO INDICATE THE YEAR IN WHICH THE KEEL WAS LAID OR WHEN THE SHIP WAS AT A SIMILAR STAGE OF CONSTRUCTION EXCEPT FOR 1952, 1965, 1980, 1981, 1984 AND 1986 IN WHICH CASES THE ACTUAL DATE SHOULD BE GIVEN.

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					1

1.0 DOCUMENTATION

1.1 **FIRE CONTROL PLANS** (Ch II-2/20)

1.1.1 To be in the national language. If language is neither English or French a translation into one of these languages is also to be included. ☐

1.1.2 Up-to-date plans permanently exhibited in an accessible location. State language. ☐

1.1.3 Duplicate set of fire plans stored outside deckhouse. ☐

1.2 **MUSTER LIST AND EMERGENCY INSTRUCTIONS** (Ch III/8 & 53)

1.2.1 Muster list including manning of fire parties and emergency procedures in a language understood by the ship's compliment are posted in several parts of the ship, particularly:

1.2.2 In the crews quarters ☐

1.2.3 In the engine room ☐

1.2.4 On the navigating bridge. ☐

1.3 **NAUTICAL PUBLICATIONS** (Ch. V/20)

1.3.1 Adequate and up-to-date charts, sailing directions, lists of lights, notices to Mariners, tide tables and other nautical publications necessary for the intended voyage are provided to the master's satisfaction. ☐

1.4 **INTERNATIONAL CODE OF SIGNALS** (Ch. V/21)

1.4.1 Copy of current edition is provided. ☐

1.5 **TRAINING MANUAL** (Ch. III/51)

1.5.1 Training manuals containing instructions and information in easily understood terms which illustrate the use of lifesaving appliances and methods of survival are provided on the ship. ☐

1.6 **INSTRUCTIONS FOR ONBOARD MAINTENANCE** (Ch. III/52)

1.6.1 Instructions for onboard maintenance of lifesaving appliances illustrated where possible are provided. ☐

1.7 **OPERATING INSTRUCTIONS** (Ch. III/9)

1.7.1 Poster or signs are provided on or in the vicinity of survival craft and their launching controls which illustrate their use. ☐

005 2.0 **SAFETY OF NAVIGATION (Ch. V/12)**

2.1	SHIPBORNE NAVIGATIONAL EQUIPMENT	*TYPE AND SERIAL NUMBER	*MANUFACTURER
2.1.1	Standard Magnetic Compass		
2.1.2	Steering Magnetic Compass or reflector to the steering position		
2.1.3	Means of communication between Standard Compass and normal navigational control position		
2.1.4	Means of taking bearings through 360°		
2.1.5	Magnetic Compass table of residual deviation		
2.1.6	Spare Magnetic Compass		
2.1.7	Gyro Compass		
2.1.8	Heading information at emergency steering position		
2.1.9	Radar (Number One)		
2.1.10	Radar (Number Two, if required)		
2.1.11	Radar plotting facilities		
2.1.12	Automatic Radar Plotting Aid (ARPA)		
2.1.13	Echo sounder		
2.1.14	Speed and distance indicator		
2.1.15	Rudder angle indicator		
2.1.16	Propeller revolution counter		
2.1.17	Propeller pitch and mode indicator		
2.1.18	Rate of turn indicator		
2.1.19	Radio direction finder		
2.1.20	2182 kHz homing on RDF		

2.2 **AUTO PILOT** (Ch. V/19)

2.2.1 Is the autopilot provided with an emergency source of power? ☐

2.2.2 Where an autopilot is fitted, clear instructions are provided at the control console on change-over procedure from automatic to manual steering and vice versa. ☐

2.2.3 Is the autopilot fitted with an off-course alarm? ☐

2.3 **STEERING GEAR** (Ch. V/19)

2.3.1 Simple operating instructions with a block diagram showing the change-over procedure for remote steering gear control systems and steering gear power units are permanently displayed on the navigating bridge and in the steering gear compartment. ☐

006 2.4 **SIGNALLING APPARATUS** (Ch. V/11) (And revised Collision Regulations 1972)

	APPARATUS	NUMBER	DESCRIPTION	LOCATION
2.4.1	Daylight signalling lamps			
	Source of power	–		
2.4.2	Forecastle bell			
2.4.3	Gong (with striker)			
2.4.4	Ship's whistle (Type & Serial No.) †			
2.4.5	3 Black Ball shapes			
2.4.6	1 Black Diamond shape			
2.4.7	Cylindrical shape*			

2.4.8 † If only one electrically powered whistle is fitted it is provided with both main and emergency power supply ☐

007 2.5 **NAVIGATION LIGHTS** (Revised Collision Regulations 1972)

2.5.1 Application of revised Collision Regulations 1972.
The following information may be obtained from plans, if available. See also diagram on page 4.

2.5.2	Horizontal distance in metres	1	Foremast light abaft top of stem	
		2	Between foremast and mainmast lights	
2.5.3	Vertical height in metres above waterline in condition of maximum trim by stern	1	Foremast light	
		2	Mainmast light	
2.5.4	Vertical height in metres above uppermast continuous deck	1	Sidelights	
		2	Foremast light	
		3	Mainmast light	

	LIGHT	OIL	ELECTRIC	MILES RANGE	TWO TIER TYPE	POWER SOURCE
2.5.5	Fore Masthead					
2.5.6	Main Masthead					
2.5.7	Port side					
2.5.8	Starboard side					
2.5.9	Stern					
2.5.10	Towing					
2.5.11	Anchor (1)					
2.5.12	Anchor (2)					
2.5.13	NUC (1)					
2.5.14	NUC (2)					

2.5.15 At least one complete set of spare bulbs is provided. ☐

2.5.16 Sidelights fitted with inboard screens painted matt black. ☐

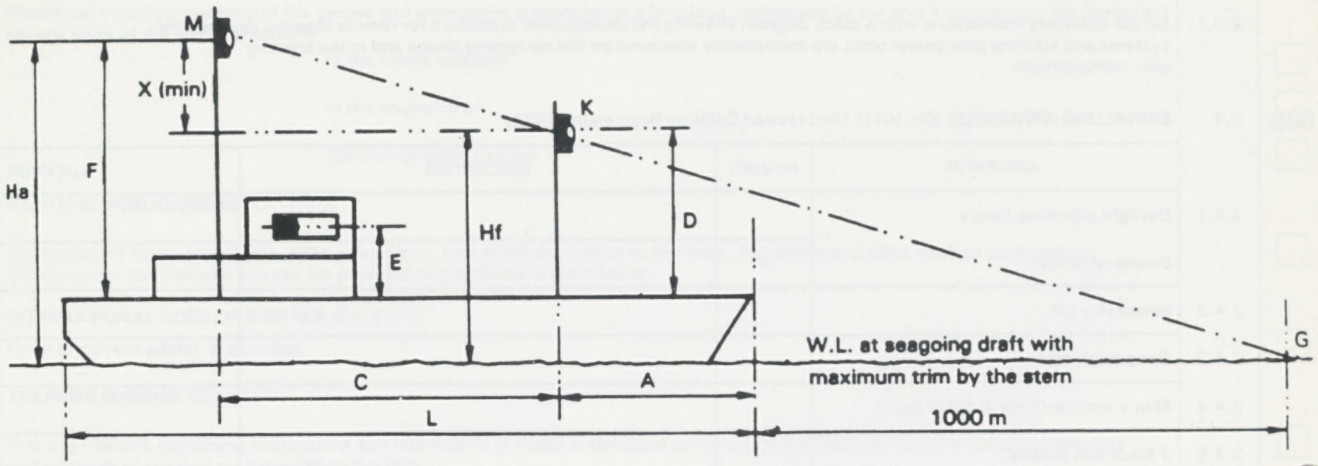
2.6 **POWER SOURCE** (Ch. II-1/41 & 43)

2.6.1 Indicate main supply (M) ☐

2.6.2 Indicate emergency supply (E) ☐

2.6.3 Indicate main and emergency supply (ME) ☐

2.7 **NAVIGATION LIGHT POSITION CHECK**



L = Length

A = Not more than 0 · 25 L [Annex I 3(a)]

B = Greatest breadth of vessel

C = Not less than 0 · 5 L need not be more than 100 m [Annex I 3(a)]

D = Not less than 6 m or B if B is more than 6 m but D need not be greater than 12 m [Annex I 2(a)(i)]

Sidelights

(a) Not in front fwd masthead light [Annex I 3(b)]

(b) At or nearside of vessel recommend not more than B/10 inboard [Annex I 3(b)]

(c) Inboard screens to be painted matt black [Annex I (5)]

E = Not more than 0 · 75 D. (D = height of fwd masthead light) [Annex I 2(g)]

F = D + 4 · 5 m minimum and such that in all normal conditions of trim the after light will be seen over and separate from the forward light at 1000 m forward of the stern at sea level
(Allow 450 mm (18") for depth of lantern) [Annex I 2(a)(ii) and 2(b)]

Hf = Height to centre of forward masthead light above the waterline in normal seagoing condition with maximum trim by the stern

Ha = Height to centre of aft masthead light above the waterline in normal seagoing condition with maximum trim by the stern

(Recommend mainmast light be positioned not less than 450 mm above point line where GK produced intersects mainmast in order that mainmast light be seen separate from and above the foremast light from point G with vessel in condition with maximum trim by stern.)

$$\frac{X\ (\text{minimum})}{C} = \frac{Hf}{A + 1000} \therefore X\ \text{Min} = \frac{C.Hf}{A + 1000} =$$

Actual 'X' = (F – D) = ( ) =

NB: With vessel on even keel and upperdeck assumed parallel to waterline (no sheer, no camber) F – D should not be less than 4 · 5 m.

2.7.1 Do the positions of the Navigation Lights comply with 1972 Collision Regulations? Yes ☐ No ☐

008 2.8 **PILOT LADDERS AND MECHANICAL PILOT HOISTS** (Ch. V/17)

2.8.1 Pilot ladder provided for embarkation and disembarkation of pilots with provisions for adequate overside lighting at night ☐

2.8.2 Lifebuoy with light and a heaving line located close by are provided ☐

2.8.3 Bulwark ladder*, OR ☐

2.8.4 Hinged rail section* ☐

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					4

009 2.8.5 Mechanical Pilot Hoist (if provided) (Ch. V/17)

MAKE		
SOURCE OF POWER		NO. AND MATERIAL OF FALLS
LENGTH	CONSTRUCTION AND SIZE	

010 2.8.6 Accommodation Ladder. (Only required for use by pilot when distance from sea level to the point of access to the ship is more than 9 metres in any seagoing conditions.)

MAKE	
LENGTH	MATERIAL

3.0 LIFE-SAVING APPLIANCES

3.1 **ROCKETS AND SIGNALS** (Ch. III/6 & 17)

		STORAGE LOCATION
011	3.1.1 Line throwing appliances with 4 rockets and lines	
012	3.1.2 12 parachute distress signals	
	3.1.3 Additional rockets and signals if provided	

3.2 **COMMUNICATIONS** (Ch. III/6)

		MAKE, TYPE AND SERIAL NUMBER	SET NUMBER	LOCATION
013	3.2.1 Survival craft portable radio		1	
	3.2.2		2	
	3.2.3		3	
014	3.2.4 Survival craft/emergency position indicating radio beacon (min 2) OR Radar transponder in lieu*		1	
			2	
015	3.2.5 Two way radiotelephone apparatus (min 3)		1	
			2	
			3	

3.2.6 On board means are provided for two-way communication between emergency control stations, muster and embarkation stations and strategic positions on the ship. ☐

3.3 **SURVIVAL CRAFT, MUSTER, LAUNCHING AND EMBARKATION ARRANGEMENT, LAUNCHING STATION, STOWAGE OF SURVIVAL CRAFT AND RESCUE BOAT** (Ch. III/11, 12, 13, 14 & 15)

3.3.1 Muster station provided close to embarkation station. ☐

3.3.2 Muster and embarkation station, survival craft and rescue boat launching appliance area of water into which survival craft and rescue boats are launched, provided with adequate lighting. ☐

3.3.3 Lighting also supplied from emergency source of power. ☐

3.3.4 Muster and embarkation stations are arranged to enable stretcher cases to be placed in survival craft. ☐

(a) An embarkation ladder in single length from the deck to the lightest seagoing waterline under unfavourable trim and list, is provided at each launching station ☐

OR

(b) one at every two adjacent launching stations. ☐

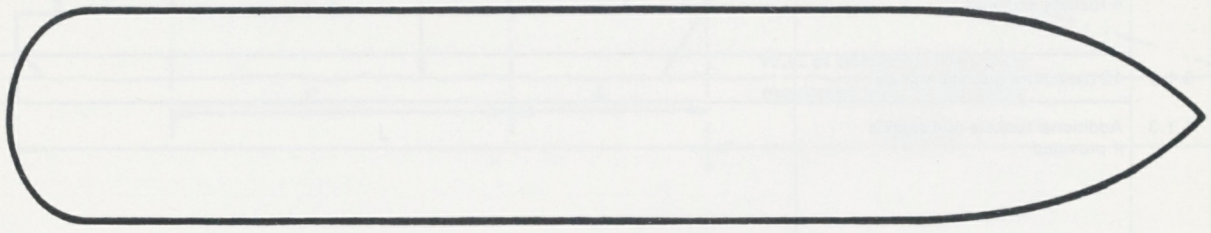
3.3.5 Launching station arranged to be clear of propeller and steeply overhanging portions of the hull. ☐

3.3.6 Survival craft and rescue boats are stowed so that they and their arrangement will not interfere with each other. ☐

3.3.7	Means are provided for preventing discharge of water into survival craft.	☐
3.3.8	If there is a danger of survival craft being damaged by ship's stabilizer fins, means powered by an emergency source of power are provided to bring the fins inboard.	☐
3.3.9	A stabilizer fin position indicator is provided on navigation bridge.	☐
3.3.10	At least two lifelines are fitted to davit spans.	☐
3.3.11	Means are provided for holding survival craft against the ship's side.	☐
3.3.12	Indicate the maximum angle of list against which survival craft can be launched if greater than 20° (Tankers, Chemical Tankers and Gas Carriers).	☐

016 3.4 **LOCATION OF SURVIVAL CRAFT AND RESCUE BOATS**

Indicate superstructures and positions of lifeboats, liferafts and rescue boats. Indicate on sketch: motor (M); mechanically propelled (MP); pulling (P); freefall (F); liferafts (LR); rescue boats (RB). Number boats from forward, odd numbers starboard side, even numbers port side.



3.5	**LIFEBOATS** (Ch. III/26)	NO. 1 (S.S.F.)	NO. 2 (P.S.F.)	NO. 3 (S.S.A.)	NO. 4 (P.S.A.)
3.5.1	Capacity – number of persons				
3.5.2	Weight – fully loaded and equipped				
3.5.3	Material of boat				
3.5.4	Length (m)				
3.5.5	Breadth (m)				
3.5.6	Depth (m)				
3.5.7	Cubic Capacity (m^3)				
3.5.8	Free-fall				
3.5.9	Totally enclosed				
3.5.10	Partially enclosed				
3.5.11	Open				
3.5.12	Motor				
3.5.13	Mechanically propelled*				
3.5.14	Rowing				
3.5.15	Self-righting				
3.5.16	With external fire protection				
3.5.17	With self-contained air supply system				
3.5.18	Manufacturer				
3.5.19	Serial Number				
3.5.20	Approval Authority				
3.5.21	Is the lifeboat used as a rescue boat?				
3.5.22	Capacity (number of persons) if less than the above and used as a rescue boat				

*Applicable only on ships keel of which was laid before 1.7.86

017	3.5.23	Simultaneous release mechanism for releasing lower fall blocks from lifting hooks is fitted.	☐
		The release hook mechanism is:	
	3.5.24	(a) Able to operate when the lifeboat is waterborne or there is no load on the hooks, and	☐
	3.5.25	(b) With a load on the hooks of 1:1 times the mass of the boat when loaded with its full complement of persons and equipment.	☐
	3.5.26	The 'on load' capability is adequately protected against accidental or premature release.	☐
	3.5.27	The launching appliance operator on the ship is able to observe survival craft at all times during launching and recovery.	☐
018	3.6	**LIFEBOAT LAUNCHING APPLIANCES** (Ch. III/48)	
	3.6.1	Launch track and recovery arrangement provided for free-fall lifeboat.	☐

3.6.2	Davits	MAKER AND TYPE		SWL
3.6.3	Winches	MAKER AND SERIAL NO.		SWL
3.6.4	Falls (Wire rope)	LENGTH AND SIZE	CONSTRUCTION	
		CORROSION RESISTANT ☐ ROTATION RESISTANT ☐		BREAKING LOAD
3.6.5	Means of launching lifeboats			
		Maximum number of persons on board the lifeboat that the launching appliance is capable of recovering		

19 3.7 **EACH LIFEBOAT IS EQUIPPED AS SHOWN BELOW** (Ch. III/41, 44)
(Enter N/A where not applicable)

		BOAT NUMBER			
		1	2	3	4
3.7.1	Number of persons the boat is certified to carry				
3.7.2	Rowing oars/steering oar if applicable				
3.7.3	Thole pin and crutch permanently attached or equivalent arrangement, one for each oar				
3.7.4	Permanent earth connection for lifeboat portable radio				
3.7.5	Plugs with chain attached, one for each drain valve				
3.7.6	Number of automatic drain valves fitted				
3.7.7	Rudder (attached) with tiller				
3.7.8	Lifeline becketed around outside of boat				
3.7.9	Bilge pumps manually operated (1)				
3.7.10	Lockers for small items of equipment				
3.7.11	Painter (1) secured to stem, (1) secured forward with release device able to operate under tension				
3.7.12	Boat hooks (2)				
3.7.13	Food ration of approved type in airtight receptacles stowed in water-tight containers totalling not less than 10 000 kJ per person				
3.7.14	Freshwater, 3 litres or 6 pints per person in water-tight receptacles or a desalting apparatus				
3.7.15	Parachute signals, red (4)				
3.7.16	Hand flares, red (6)				
3.7.17	Buoyant smoke signals, orange (2)				
3.7.18	Baler, buoyant (1)				
3.7.19	Buckets with lanyard (2)				
3.7.20	Hatchets with lanyard (2), one at each end of boat				
3.7.21	Compass in binnacle, efficiently luminized or illuminated				
3.7.22	Sea anchor (1) with shock resistant hawser and a tripping line				
3.7.23	Dipper, rust proof with lanyard (1)				
3.7.24	Graduated drinking vessel, rust proof (1)				

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					7

		LIFEBOAT EQUIPMENT CONTINUED	1	2	3	4
	3.7.25	First aid outfit, approved type in watertight case (1)				
	3.7.26	Electric torch, waterproof, suitable for morse code signalling (1), with spare set of batteries and spare bulb in waterproof container				
	3.7.27	Daylight signalling mirror (1)				
	3.7.28	Jack-knife attached to boat with lanyard (1)				
	3.7.29	Whistle or equivalent sound signal (1)				
	3.7.30	Fishing tackle (1 Set)				
	3.7.31	Lifesaving signals on a waterproof card or in a waterproof container				
	3.7.32	Short ladder or other means of climbing into upright boat from the water				
	3.7.33	Skates or fenders (and skids if required) to facilitate launching against adverse list				
	3.7.34	Hand holds on underside of hull (only required on non self-righting lifeboats)				
	3.7.35	A survival manual				
	3.7.36	Six doses of anti-seasickness medicine per person				
	3.7.37	One seasickness bag per person				
	3.7.38	Tin openers (3)				
	3.7.39	Buoyant rescue quoit (2) attached to not less than 30 m of buoyant line				
	3.7.40	Searchlight (1)				
	3.7.41	Efficient radar reflector (1)				
	3.7.42	Thermal protective aids (for 10% or 2 persons whichever is the greater)				
	3.7.43	Manually controlled internal and external lamps able to be operated for at least 12 hours				
	3.7.44	Sufficient tools for minor adjustments to the engine and its accessories				
	3.7.45	A safety belt fitted at each seating position				
	3.7.46	Arrangement provided for siting and securing portable radio				
020	3.8	**ADDITIONAL REQUIREMENTS FOR PARTIALLY ENCLOSED LIFEBOATS IF VESSEL TRADES ON RESTRICTED SERVICE** (Ch. III/42)				
	3.8.1	An effective means of bailing, OR				
	3.8.2	The lifeboat is fitted with automatic self-bailing arrangements				
	3.8.3	A permanently attached foldable rigid anti-exposure cover in way of open part of boat				
	3.8.4	Foldable cover is provided with means of collecting water				
021	3.9	**MOTOR LIFEBOATS**				
	3.9.1	Engine type, diesel (D)				
	3.9.2	B.H.P. of engine				
	3.9.3	Starting system with two independent rechargeable energy sources				
	3.9.4	Speed ahead in smooth water fully loaded (knots)				
	3.9.5	Fuel capacity sufficient for 24-hours running, litres/gallons				
	3.9.6	Fire extinguisher, portable, suitable for oil fires				
	3.9.7	Propeller guard is provided				
	3.9.8	Exhaust pipe is provided with means to prevent ingress of water to engine				
	3.9.9	Engine transmission and accessories are enclosed in the fire retardant casing				
	3.9.10	Means are provided for recharging engine starting, radio and searchlight batteries				
	3.9.11	Water resistant instructions for starting and operating the engine are provided				

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					8

			1	2	3	4
022	3.10	**MARKING OF BOATS** (Ch.III/41)				
	3.10.1	Dimensions and number of persons it is permitted to carry permanently marked thereon				
	3.10.2	Name and Port of Registry of the ship to which the lifeboat belongs painted on each side of the bow				
	3.10.3	It is possible to identify the ship to which the lifeboat belongs and the number of the lifeboat from above				
023	3.11	**RIGID LIFERAFT EQUIPMENT**				
	3.11.1	Number of persons the liferaft is certified to carry				
	3.11.2	Painter attached (1) of length not less than twice the distance from the stowed position to the waterline at lightest seagoing draft or 15 m whichever is greater				
	3.11.3	Lifeline around outside of liferaft				
	3.11.4	Lifeline around inside of liferaft				
	3.11.5	Sea anchors (1 permanently attached and 1 spare) with shock resistant hawser and tripping line				
	3.11.6	Buoyant battery light attached to lanyard (1)				
	3.11.7	Food ration totalling not less than 10,000 kJ for each person				
	3.11.8	Fresh water in watertight receptacles (1½ litres or 3 pints per person)				
	3.11.9	Anti-seasickness medicine, 6 doses per person				
	3.11.10	One seasickness bag for each person raft is certified to carry				
	3.11.11	Buoyant paddles (2)				
	3.11.12	First Aid outfit, approved type in waterproof case (1)				
	3.11.13	Parachute signals, red (4)				
	3.11.14	Buoyant smoke signals (2)				
	3.11.15	Hand flare, red (6)				
	3.11.16	Buoyant rescue quoit with 30 m (100ft) buoyant line attached (1)				
	3.11.17	Knife, 1 for rafts carrying not more than 12 persons, 2 if 13 or more persons carried				
	3.11.18	Baler, 1 for rafts carrying not more than 12 persons, 2 if 13 or more persons carried				
	3.11.19	Sponges (2)				
	3.11.20	Tin openers (3)				
	3.11.21	Graduated drinking vessel, rustproof (1)				
	3.11.22	Electric torch, waterproof, suitable for Morse code signalling (1), with spare set of batteries and spare bulb in waterproof case				
	3.11.23	Daylight signalling mirror (1), with instructions				
	3.11.24	Signalling whistle or sound signal (1)				
	3.11.25	Fishing tackle (1 set)				
	3.11.26	Survival instructions				
	3.11.27	Lifesaving signals, illustrated table on waterproof card or in a waterproof container (1)				
	3.11.28	An efficient radar reflector				
	3.11.29	Instructions for immediate action				
	3.11.30	Manually operated internal and external lamp visible at a distance of at least 2 miles for not less than 12 hours				
	3.11.31	Thermal protective aids for 10% of persons carried or 2 persons, whichever is the greater				
	3.11.32	Arrangements for siting and securing the antenna for the portable radio				

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					9

024 3.12 **MARKING OF RIGID LIFERAFTS** (Ch. III/40)

Each rigid liferaft is marked with:

3.12.1 The name and port of registry of the ship to which it belongs. ☐

3.12.2 The maker's name or trademark. ☐

3.12.3 The serial number of the raft. ☐

3.12.4 The name of the approving authority. ☐

3.12.5 At each entrance, the number of persons it is certified to accommodate. ☐

3.12.6 SOLAS A pack. ☐

3.12.7 Length of painter (State actual length). ☐

3.12.8 Launching instructions. ☐

3.12.9 The maximum permitted stowage height above the waterline. Permitted stowage height ☐ Actual stowage height ☐ ☐

025 3.13 **INFLATABLE LIFERAFTS** excluding any additional liferaft stowed forward or aft for compliance with Regulation 26.3.2 (Ch. III/26, 38, 39 & 40)

	NO.	DESCRIPTION	MAKER'S NAME & SERIAL NUMBER	NO. OF PERSONS	LOCATION	APPROVAL AUTHORITY	DAVIT LAUNCHED YES/NO	TRANSFERABLE SIDE TO SIDE YES/NO
3.13.1								
3.13.2								
3.13.3								
3.13.4								
3.13.5								

026 3.14 **ADDITIONAL LIFERAFT FORWARD OR AFT** (Ch. III/26)

	DESCRIPTION	MAKER'S NAME & SERIAL NUMBER	NO. OF PERSONS	LOCATION	APPROVAL AUTHORITY	DATE OF MANUFACTURE
3.14.1						

027 3.15 **LIFERAFT LAUNCHING ARRANGEMENTS** (Ch. III/29)

3.15.1 Each liferaft stowed with its pointer permanently attached to the ship. ☐

3.15.2 Each liferaft stowed able to float free from the ship. ☐

3.15.3 If stowed lashed, is each liferaft lashing fitted with hydrostatic release. (Not applicable to rafts carried for compliance with Reg. 26.1.4.) ☐

3.15.4 If liferaft is davit launched is release hook only able to operate in the "no load" condition. ☐

3.15.5	LIFERAFT DAVIT MAKER & TYPE	SWL	CRANE MAKER & TYPE	SWL

028 3.16 **MARKING OF INFLATABLE LIFERAFT CONTAINERS** (Ch. III/39)

Each liferaft container marked with:

3.16.1 The maker's name or trademark. ☐

3.16.2 The serial number of the raft. ☐

3.16.3 The name of the approving authority. ☐

3.16.4 Type of emergency pack enclosed. ☐

3.16.5 Length of painter (State actual length). ☐

3.16.6 The maximum permitted stowage height above the waterline. Permitted stowage height ☐ Actual stowage height ☐ ☐

3.16.7 Launching instructions. ☐

3.16.8 Last date of service. ☐

029 3.17 **RESCUE BOAT** (Ch. III/47)

	BOAT NUMBER	TYPE, MATERIAL AND IDENTIFICATION NUMBER	CERTIFIED FOR: NUMBER OF PERSONS	CERTIFIED FOR: WEIGHT – FULL LOAD	INTERNAL BUOYANCY MATERIAL	APPROVED BY
3.17.1						

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					10

030

3.18	**RESCUE BOAT EQUIPMENT – GENERAL REQUIREMENTS**	NO. PROVIDED
3.18.1	Sufficient oars or paddles to make headway in calm sea	
3.18.2	Thole pins, crutches or equivalent for each oar	
3.18.3	Thole pins or crutches attached by lanyard or chain	
3.18.4	Buoyant baler (1)	–
3.18.5	Binnacle containing an efficient luminous compass (1)	–
3.18.6	Sea anchor with tripping line at least 10 m in length (1)	–
3.18.7	Painter of sufficient length and strength at fore end (1)	–
3.18.8	Buoyant line not less than 50 m in length of sufficient strength to tow a liferaft (1)	–
3.18.9	Waterproof electric torch for message signalling (1)	–
3.18.10	Spare set of batteries and bulb in watertight container (1)	–
3.18.11	One whistle or equivalent sound signal (1)	
3.18.12	First Aid kit in watertight case (1)	–
3.18.13	Buoyant quoits attached to line at least 30 m length (2)	–
3.18.14	A searchlight able to efficiently illuminate a light coloured object at night which has a width of 18 m at a distance of 180 m	–
3.18.15	A searchlight able to operate continuously for at least 3 hours	–
3.18.16	An efficient radar reflector	–
3.18.17	Thermal protective aids for at least 10% of complement or 2 persons, whichever is the greater	
3.19	**ADDITIONAL REQUIREMENTS FOR RIGID RESCUE BOATS**	
3.19.1	A boat hook	–
3.19.2	A bucket	–
3.19.3	A knife or hatchet	
3.20	**ADDITIONAL REQUIREMENTS FOR INFLATABLE RESCUE BOATS**	
3.20.1	A buoyant safety knife	–
3.20.2	Two sponges	–
3.20.3	An efficient manually operated bellows or pump	
3.20.4	A puncture repair kit in a suitable container	–
3.20.5	A safety boat hook	–

031

3.21 **LAUNCHING AND RECOVERY ARRANGEMENTS FOR RESCUE BOAT** (Ch. III/16)

Launching appliance (Ch. III/15, 16 & 48)

3.21.1	Crane	MAKER & TYPE		SWL
3.21.2	Davit	MAKER & TYPE		SWL
3.21.3	Winch	MAKER & SERIAL NO.		SWL
3.21.4	Falls (Wire rope)	CORROSION RESISTANT ☐ ROTATION RESISTANT ☐	LENGTH & SIZE	
		CONSTRUCTION	BREAKING LOAD	

3.21.5 The rescue boat is able to be recovered from the the water with its full complement of persons and equipment at a speed of at least 0.3 m/sec. ☐

3.21.6 The rescue boat is able to be launched with the parent vessel moving ahead at 5 knots. ☐

032

3.22 **RESCUE BOAT ENGINE DETAILS**

3.22.1	TYPE OF ENGINE	SERIAL NUMBER	FUEL TANK CAPACITY

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					11

3.23	**MARKING OF RESCUE BOAT** (Ch. III 41/47)				
3.23.1	Dimensions and number of persons it is certified to carry permanently marked thereon.				☐
3.23.2	Name and port of registry of the ship to which the rescue boat belongs painted on each side of the bow.				☐
3.23.3	Is the rescue boat marked so that, from above, the ship to which it belongs can be identified.				☐
3.24	**OTHER LIFE SAVING APPLIANCES** (Ch. III/7 & 27)				
		NO.	MAKE AND TYPE	LOCATION	
033 3.24.1	Life jackets with whistle attached				
034 3.24.2	Life jackets with whistle and light				
	Additional: For persons on watch				
	For remote survival craft stations				
	If required, for children				
035 3.24.3	Lifebuoys with lights and smoke signals and capable of quick release from navigation bridge				
3.24.4	Lifebuoys with self-igniting lights only				
3.24.5	Lifebuoys with buoyant lifeline of length not less than twice the height from the stowed position to the lightest seagoing waterline or 30 m, whichever is the greater				
3.24.6	Lifebuoys without attachments				
3.24.7	Immersion suits				
036 3.24.8	Thermal protective aids				
037 3.24.9	All survival craft, lifebuoys and lifejackets are fitted with retro-reflective material.				☐
4.0	**FIRE EXTINGUISHING ARRANGEMENTS (Ch. II/2)**				
4.1	**PUMPS, FIRE MAIN, HYDRANTS, HOSES, Etc.** (Ch. II-2/4)				
	Fire pumps and fire main.				
038	FIRE PUMPS	NO.	CAPACITY	PRIME MOVER	LOCATION
4.1.1					
4.1.2					
4.1.3					
039 4.1.4	Emergency Fire Pump*				
4.1.5	* If diesel driven: Means of starting.				
	Fuel tank capacity.				
4.1.6	* If electrically driven: Source of emergency power.				
	Location of emergency power.				
4.1.7	Fire main diameter.				
4.1.8	Location of machinery space fire main riser isolating valves.				
040 4.1.9	Location of fire main isolating valves on tank deck (Tankers only).				
4.1.10	Relief valves fitted if pumps capable of developing pressure exceeding the design pressure of service pipe.				☐

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					12

4.1.11	Relief valves locations.		
4.1.12	If applicable, state which pump(s) is/are: a) Remote controlled from bridge or fire control station OR		
4.1.13	b) Capable of maintaining permanent pressurisation of firemain system.		

041 4.2 **HYDRANTS** (Ch. II-2/4)

	LOCATION	NUMBER	DIAMETER	TYPE OF COUPLING
4.2.1	Machinery spaces			
4.2.2	Accommodation			
4.2.3	Weather decks			
4.2.4	Other spaces			

042 4.3 **HOSES AND NOZZLES** (Ch. II-2/4)

	LOCATION	NUMBER	DIAMETER	LENGTH	MATERIAL	SPRAY/JET NOZZLE WITH SHUT-OFF
4.3.1	Machinery spaces					
4.3.2	Accommodation					
4.3.3	Weather decks					
4.3.4	Other spaces					

043 4.4 **SAND BOXES AND SCOOPS** (Ch. II-2/7) If provided

	NUMBER	LOCATION(S)
4.4.1		

044 4.5 **INTERNATIONAL SHORE CONNECTION** (Ch. II-2/19)

	NUMBER	LOCATION(S)
4.5.1		

045 4.6 **FIRE EXTINGUISHERS** (Ch. II-2/6 & 7)

	ITEM	LOCATION	NUMBER	TYPE	CAPACITY	NUMBER OF SPARE CHARGES†
4.6.1	Portable extinguishers	Machinery spaces				
4.6.2		Accommodation spaces				
4.6.3		Service spaces				
046 4.6.4	Portable Foam applicator units	Machinery spaces				
		Other spaces				
4.6.5	Non-portable extinguishers	Machinery spaces				
		Other spaces				

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					13

† ALTERNATIVE DUPLICATE EXTINGUISHERS MAY BE PROVIDED

047 4.7 **FIREMAN'S OUTFITS** (Ch. II-2/17)

NO.	LOCATION	FIREMAN'S OUTFIT							SELF-CONTAINED BREATHING APPARATUS				
		PROT. SUIT	BOOTS GLOVES	RIGID HELMET	SAFETY LAMP	AXE	LIFE-LINE	SFTY BELT HARNESS	TYPE	MANF.	CAP.	FUNCT. PERIOD	SPARE CYL.*

* Alternatively approved recharging facilities provided with at least one spare cylinder per self-contained breathing apparatus fitted

4.8 **SMOKE HELMET OR SMOKE MASK WITH AIR PUMP AND HOSE, IF PROVIDED**

NO.	MAKE	LOCATION

048 4.9 **FIXED FIRE EXTINGUISHING & PROTECTION SYSTEMS**

NO.	SPACE PROTECTED	CO_2	HALON	FIXED FOAM	FIXED PRESSURE WATER SPRAYING	AUTOMATIC SPRINKLER SYSTEM	DRY POWDER	INERT GAS SYSTEM	OTHERS

049 4.10 **DETAILS OF FIXED FIRE EXTINGUISHING AND PROTECTION SYSTEMS**

4.10.1 CO_2 System(s) (Ch. II-2/5)

SPACE PROTECTED	STORAGE CONTAINERS			LOCATION OF REMOTE CONTROL STATION	TYPE OF AUDIBLE ALARM	LOCATION OPERATING INSTRUCTIONS POSTED
	NUMBER	CAPACITY EACH	LOCATION			

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					14

4.11 **IF NO FIXED FIRE EXTINGUISHING SYSTEM IS FITTED IN CARGO SPACES** (Ch. II-2/53.1.2)

The following must apply:

4.11.1 a) Hatch covers are of steel and effective means are provided for closing all ventilators and other openings leading to holds, and ☐

4.11.2 b) The ship is constructed and solely intended for carrying ore, coal, grain, unseasoned timber and non combustible cargo or cargoes which are considered to constitute a low fire risk, and ☐

4.11.3 c) Ventilator fans can be stopped and doorways, ventilators and all other openings to cargo spaces can be closed from outside the space concerned. ☐

050 4.12 **HALOGENATED SYSTEM(S) (HALON)** (Ch. II-2/5)

SPACE PROTECTED	1301/1211	STORAGE CONTAINERS			LOCATION OF REMOTE CONTROL STATION*	TYPE OF AUDIBLE ALARM	LOCATION OF OPERATING INSTRUCTIONS
		NUMBER	CAPACITY EACH	LOCATION			

* Indicate automatic (A) or manual (M) release of system.

N.B. Only secondary systems are permitted to be fitted with automatic release (See Ch. II-2/5.34)

Automatic stop for all ventilation fans serving the protected space is provided. ☐

051 4.13 **FIXED FOAM SYSTEM(S)** (Ch. II-2/8, 9 & 61)

DETAILS		SPACE PROTECTED		
		ENGINE/BOILER ROOM	CARGO AREA DECK/CARGO TANK	CARGO PUMP ROOM
Foam	Type			
	Manufacturer			
	Quantity			
	Application Rate			
	Concentration Ratio OR Expansion Ratio			
Pump	Type			
	Location			
	Capacity			
	Location of Controls			
Location of Foam Tank				
Location of Controls				

Manufacturer's service instruction manual is provided. ☐

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					15

Means of Supply	MONITORS ON TANK DECK	MANUFACTURER		CAPACITY
		TYPE		NUMBER
	Applicators	DETAILS	MACHINERY SPACES	TANK DECK
		Manufacturer		
		Type		
		Number		
	Number of Hydrants			
	Number of Hoses			

Isolating valves are fitted immediately forward of deck monitors. ☐

Fire main and deck foam main are combined systems. ☐

052 4.14 **FIXED PRESSURE WATER SPRAYING SYSTEM(S)** (Ch. II-2/10)

SPACE PROTECTED	PUMPS*		NOZZLES TYPE AND MAKE	APPLICATION RATE LITRES/Sq.M	LOCATION OF REMOTE CONTROL STATION
	LOCATION	CAPACITY			

* If Diesel Driven	MEANS OF STARTING	FUEL TANK CAPACITY
* If Electrically Driven	SOURCE OF EMERGENCY POWER	LOCATION OF EMERGENCY POWER SOURCE

053 4.15 **AUTOMATIC SPRINKLER, FIRE DETECTION AND FIRE ALARM SYSTEM** (Ch. II-2/12) See also 5.1 method IIC

SPACE PROTECTED	AUTOMATIC INDEPENDENT POWER PUMP†		SOURCES OF POWER	SECTION PLAN AND INSTRUCTION PROVIDED	LOCATION OF STOP VALVES
	LOCATION	CAPACITY			

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					16

4.15 (cont.) † Electrically Driven Pump	SOURCE OF EMERGENCY POWER	LOCATION OF EMERGENCY POWER

Fresh water tank capacity

Sprinkler heads

TYPE	MANUFACTURER	TOTAL NUMBER OF SPARES

Location of automatic audible and visual alarms for each section of sprinklers

Location of selection isolating stop valves

Are section isolating stop valves fitted with means of locking? ☐

Location of cross-connection valve to firemain

054 4.16 **INERT GAS SYSTEM** (Ch. II-2/62)

Deadweight of ship TONS

Type of system a) Flue gas ☐

b) Gas generator ☐

c) Gas turbine ☐

Date of installation of system

Operational and service manual provided ☐

4.17 **GENERAL REQUIREMENTS FOR ALL INERT GAS SYSTEMS**

Is the system capable of producing a gas delivery rate 25% in excess of the maximum rated capacity of the cargo pumps? ☐

Gas scrubber location

Gas blowers, number fitted and location

Gas regulating valve location

Deck waterseal location

Other non-return devices, type and location

Means of isolating each cargo tank ☐ Stop valve ☐ Spade

Combination Carriers only: Are blank flanges provided? ☐

Ventilation arrangements—are satisfactory arrangements provided? ☐

Purging arrangements—are satisfactory means provided? ☐

Pressure vacuum devices, number and location

Are satisfactory means provided for continuously indicating the inert gas temperature and pressure at discharge side of blower when operating? ☐

Are instrumentation and alarms provided as per manual? ☐

Ullage system—is a closed system fitted? ☐

GAS CONCENTRATION MEASUREMENT	NUMBER	MAKE AND TYPE
1. Portable explosion meters		
2. Portable oxygen level meters		

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE 17

4.18 **ADDITIONAL REQUIREMENTS—FLUE GAS SYSTEMS ONLY**

Flue gas isolating valves, number and location

4.19 **ADDITIONAL REQUIREMENTS—GAS GENERATORS AND GAS TURBINE SYSTEMS**

Fuel oil pumps, number and location

4.20 **GAS WARNING SYSTEM ON COMBINATION CARRIERS** (Ch. II-2/59)

Approved fixed gas warning system in—

a) Cargo pumprooms ☐

b) Pipe ducts ☐

c) Cofferdams adjacent to slop tanks ☐

055 4.21 **DRY POWDER SYSTEM(S)**

PROTECTED SPACES	STORAGE CONTAINER(S)			NUMBER OF HOSES/MONITORS	TYPE OF AUDIBLE ALARM	LOCATION OF REMOTE CONTROL STATION
	NUMBER	CAPACITY EACH	LOCATION			

056 4.22 **GALLEY EXHAUST PROTECTIVE SYSTEM** (Ch. II-2/16.7.4)

Type of system

Number of cylinders

Total capacity

Location of controls

Location of exhaust fan shut-off control(s)

4.23 **OTHER SYSTEM(S)—GIVE DETAILS**

057 5.0 **FIRE PROTECTION, FIRE DETECTION AND ALARM SYSTEMS**

5.1 **METHOD OF FIRE DETECTION AND ALARM SYSTEMS IN ACCOMMODATION AND SERVICE AREAS** (Ch. II-2/42 and 52)

METHOD Ic — Fixed fire detection and fire alarm system of approved type to provide smoke detection and manually operated call points in all corridors, stairways and escape routes within accommodation spaces ☐

METHOD IIc — Automatic sprinkler, fire detection and fire alarm system of an approved type to protect accommodation spaces, galleys and other service spaces, except spaces which afford no substantial fire risk such as void spaces, sanitary spaces, etc. in addition to the system(s) required for method Ic above. ☐

METHOD IIIc — Fixed fire detection and fire alarm system of an approved type to detect the presence of fire in all accommodation spaces and service spaces, except spaces which afford no substantial fire risk such as void spaces, sanitary spaces etc. ☐

5.2 **FIXED FIRE DETECTION AND FIRE ALARM SYSTEMS** (Ch. II-2/13) (*See* Page 16, 4.15)

(*See* Approved Fire Control Plan for locations of detectors and alarms)

FIRE DETECTOR MAKE AND TYPE	NUMBER	SPACE COVERED

FIRE ALARM MAKE AND TYPE	NUMBER	SPACE COVERED

Control panel location

Indicator unit(s) location(s)

Visual and audible signal at control panel for fault in power supply or electric circuits ☐

Fire and/or general alarm (audible) automatically activated throughout accommodation, service spaces, control stations, machinery spaces if response to fire signal not acknowledged within 2 minutes ☐

Manually operated fire alarm call points located throughout accommodation spaces, service spaces and control stations ☐

Suitable instructions and components spares for testing and maintenance provided ☐

Automatic release arrangements for self-closing fire doors provided at the control panel ☐

058 5.3 **GENERAL ALARM** (Ch. III/50)

Means of abandon ship warning

Location of control(s)

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					19

059 6.0 **EMERGENCY CONTROL/SPECIAL ARRANGEMENTS IN MACHINERY AND ACCOMMODATION SPACES (Ch. II-2/11)**

6.1 **MEANS FOR STOPPING VENTILATION FANS AND PUMPS AND SHUTTING OFF OIL FUEL SUCTION PIPES**

EQUIPMENT		MEANS AND LOCATIONS
Ventilation Fans	Accommodation	
	Machinery Spaces	
Oil Fuel Units		
Oil Fuel Transfer Pump		
Boiler Fans		
Oil Fuel and Lub. Oil Tank Valves		
Others		

The following are able to be closed from outside the space concerned:

a) Ventilator dampers ☐

b) Funnel openings ☐

c) Skylights ☐

d) Doorways ☐

e) Tunnel door ☐

060 7.0 **EMERGENCY ELECTRIC POWER (Ch. II-1/43, 44)**

7.1	Source of Power Including Rating or Capacity and Location	
7.2	If Generator, Means of Starting	
7.3	Services Supplied	
061 7.4	Location of Emergency Switch board	

8.0 **SPECIAL ARRANGEMENTS FOR CERTAIN SHIPS**

8.1 **PERIODICALLY UNATTENDED MACHINERY SPACE** (Ch. II-2/14)

Fire detection and fire alarm system fitted ☐

Audible and visual alarm fitted on the navigation bridge ☐

Audible and visual alarm fitted in engineer officers' office ☐

Location where a responsible crew member is on duty

Location of remote controls for sea inlets, discharges below the waterline or bilge injection where installed in periodically unattended machinery space

8.2 **RO/RO CARGO SPACES** (Ch. II-2/53.2) (And other cargo spaces intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion).

Fire detection and fire alarm system fitted ☐

Fire extinguishing arrangements provided ☐

Special drainage/pumping system provided, OR ☐

relevant stability information contained in Stability Booklet approved — DATE — PLACE

Portable extinguishers at each access ☐

Each Ro/Ro cargo space provided with at least 3 water fog applicators and 2 portable foam applicators ☐

Power ventilation system fitted ☐

Number of air changes per hour

Indication of loss of ventilating capacity at the navigating bridge ☐

Position of ventilation shut-down and closing arrangements in case of fire

Number of portable gas detection units

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					20

9.0 **ADDITIONAL INFORMATION**

ITEM* NUMBER	

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					21

*IF APPLICABLE

10.0 **EQUIPMENT RENEWALS, ALTERATIONS AND/OR ADDITIONS EFFECTED SINCE THE RECORD WAS PREPARED**

ITEM NUMBER	DESCRIPTION	SURVEYOR	PORT	DATE

change of gross tonnage and in such cases, the tonnage figure should not be entered unless the new tonnage is known. The keel-laying date is required to define whether the ship is a "new ship" or an "existing ship". This may be indicated by year only except for 1952, 1965, 1980, 1984 and 1986 when the actual day, month and year is required in order to determine which Convention and/or set of amendments is applicable, either in full or in part.

Where applicable the previous name and nationality, should be stated as this is helpful when the case is being examined in H.Q. as also is the name of any sister ships.

Some National Authorities allow more than one ship to have the same name therefore the L.R. number is of assistance in identifying the case under consideration.

Classification particulars from the Register Book in respect of the hull only are required. These should include details of any restricted service limits.

Particulars are required of the Company which actually manages the ship, pays the fees and receives all correspondence and documents. This information is of upmost importance and of great assistance in ensuring that certificates and correspondence are forwarded to the correct address.

The length at 85 per cent of the depth will be found on the LoadLine Certificate.

003 Total Number of Persons Provided For

The total number of persons provided for by life-saving appliances is not to be confused with the actual number of persons carried. The number of persons provided for by life-saving appliances is equal to the lowest of any of the following:-

For Pre '83 ships

(a) The total number of persons in the port lifeboat(s).
(b) The total number of persons in the starboard lifeboat(s).
(c) Twice the aggregate capacities of liferafts, but excluding any liferaft carried forward.
(d) The number of lifejackets provided. (Total number less the number of any additional lifejackets required to be carried).

For '83 ships

(a) The total number of persons in the port lifeboat(s).
(b) The total number of persons in the starboard lifeboat(s) or, in lieu of lifeboats P. & S. the total number of persons in the stern free fall lifeboat(s).
(c) The total aggregate capacity of the liferafts but excluding any liferaft carried forward of aft. (Special consideration required on ships less than 85m length).
(d) The total number of lifejackets provided. (Total number less the number of any additional lifejackets required to be carried).

004 New/Existing Ships

"New ships" are those ships the keels of which were laid or at an equivalent stage of construction on or after the date of entry into force of the particular convention or set of amendments. (See Part I Table 1). All other ships are "existing ships".

005 Safety of Navigation

SOLAS 1974 introduced a requirement for various items of navigational equipment to be examined during survey for the issue of a Cargo Ship Safety Equipment Certificate viz:-

(i) Gyro compass (fitted in addition to a magnetic compass)
(ii) Echo sounding device
(iii) Radar and radar plotting facilities
(iv) Radio direction finder

It should be noted that although the requirements for Radar and Radio Direction Finder equipment to be fitted is contained in Chapter V, Safety of Navigation, the record of provision of such equipment is made on the Cargo Ship Radiotelegraphy Certificate.

The 1981 Amendments to SOLAS 1974 considerably extend the amount and type of navigational equipment required to be fitted and is dependent on the tonnage of the ship. The required equipment is given in Table 2.

The relevant IMO performance specifications for navigational equipment installed on ships on or after 1st September 1984 are:-

(i) Shipborne navigational equipment:
General requirements for electronic navigational aids (Resolution A.281 (VIII));
Performance standards for magnetic compasses (Resolution A.382(X));
Performance standards for gyro compasses (Resolution A.424(XI));
Performance standards for automatic pilots (Resolution A.342(IX));
Performance standards for navigational radar equipment (Resolution A.222(VII), Resolution A.278(VIII) and Resolution A.477(XII));
Performance standards for automatic radar plotting aids (ARPA) (Resolution A.422(XI));
Performance standards for shipborne receivers for use with differential Omega (Resolution A.479(XII));
Performance standards for echo-sounding equipment (Resolution A.224(VII));
Performance standards for devices to indicate speed and distance (Resolution A.478(XII));
Performance standards for radio direction-finding systems (Resolution A.223(VII));

(ii) Related equipment:
Performance standards for radar beacons and transponders (Resolution A.423(XI));
Performance standards for radar reflectors (Resolution A.384(X));
Performance standards for differential Omega correction transmitting stations (Resolution A.425(XI));
Operational tests during survey should include the following as a minimum.

When equipment has to be run for survey purposes, it must only be operated by a duly authorised Owner's representative which should preclude any possibility of damage to the equipment or of risk to the ship's crew. If the Owner is not represented then a Surveyor should only proceed with tests if confident it is safe so to do and then only with the approval of the ship's Master.

NOTES

SOLAS 1974 Chapter V Safety of Navigation 1981 amendments Regulation 12. Shipborne Navigational Equipment Item	Reg 12 Paragraph Number	Requirements for ships ≥500 gross tons engaged on international voyages Gross Tonnage					
		≥500 but <1 600	≥1 600 but <10 000	≥10 000 but <100 000	≥100 000	Remarks	
Standard magnetic compass	(b)(i)(i)	A	A	A	A	See note 2	*
Steering magnetic compass	(b)(i)(2)	A	A	A	A	" " 1	√ *
Means of communication between standard compass position and normal navigation control position	(b)(i)(3)	A	A	A	A	—	*
Means of taking bearings through 360°	(b)(i)(4)	A	A	A	A	—	√ *
Magnetic compass table or curve of residual deviations	(b)(ii)	A	A	A	A	—	
Spare magnetic compass	(b)(iii)	A	A	A	A	See note 3	*
Gyro compass	(d)	N_1	A	A	A	" " 4	
Heading information	(f)	A	A	A	A	" " 9	
Radar (one or two)	(g) and (h)	N_1	A	A	A	" " 5	
Radar plotting facilities	(i)	N_1	A	A	A	" " 5	
Automatic radar plotting aid	(j)	—	—	N_1 and E_1	N_1 and E_1	" " 8	
Echo sounder	(k)	N_2	A	A	A	—	
Speed and distance indicator	(l)	N_1	N_1	A	A	See note 6	
Rudder angle indicator	(m)	N_1	A	A	A	" " 7	
Propellor revolution counter	(m)	N_1	A	A	A	" " 7	
Propellor pitch and mode indicator	(m)	N_1	A	A	A	" " 7	
Rate of turn indicator	(h)	—	—	—	N_1	—	
Radio direction finder	(p)	—	A	A	A	See note 10	
Homing on 2182 kHz	(q)	—	N_2	N_2	N_2	—	

Key

A = Required on any ship regardless of date of build
N_1 = Required on ships built on or after 1-9-84
N_2 = Required on ships built on or after 25-5-80
E_1 = Required on some ships built before 1-9-84 (see note 8)
√ = Required on vessels <150 gross tons
* = Required on vessels >150 but <500 gross tons

NOTES

1. Is required unless heading information provided by the standard compass (if fitted, see Note 2) is made available and is clearly readable by the helmsman at the main steering position.
2. Exemption may be granted from this Requirement providing that in all cases a suitable steering compass is carried and the Administration considers the provision of a standard magnetic compass unreasonable or unnecessary, having taken into account the nature of the voyage, the ship's proximity to land or the type of ship.
3. Required and to be interchangeable with the standard compass unless a steering compass or gyro compass is fitted.
4. The master gyro compass or a gyro repeater shall be clearly readable by the helmsman at the main steering position. Additionally, on ships of 1600 gross tons and upwards, a gyro repeater or repeaters shall be suitably placed for taking bearings as nearly as practicable over an arc of the horizon of 360°.
5. Two radars, operationally independent of each other, are required on ships of 10 000 gross tons and upwards. Radar plotting facilities on vessels of 1 600 gross tons and upwards, constructed on or after 1st September 1984, are to be at least as effective as a reflection plotter.
6. All ships required to be fitted with automatic radar plotting aid are to be fitted with a device to indicate speed and distance through water.
7. Indicators which can be read at the conning position are required to be fitted.
8.

Time scale for retro fit "Ei"	GROSS TONNAGE			
GROUP OF SHIPS	≥10 000 <15 000	≥15 000 <20 000	≥20 000 <40 000	≥40 000
TANKERS Ei	1st January 1986	1st January 1986	1st January 1986	1st January 1985
SHIPS NOT TANKERS Ei		1st September 1988	1st September 1987	1st September 1986

9. Heading information is required to be provided at the emergency steering position on all ships fitted with such a position.
10. The Administration may exempt any ship of less than 5 000 gross tons from this Requirement.

Table 2. Navigational Equipment

Following are guidance notes for suggested operational tests during survey:-

(a) Magnetic Compasses (including any spares) The freedom of movement of the gimbal system should be confirmed. The card should float freely and level and rotate without undue friction. If the compass is deflected by about 10 degrees and after a light tap on the bowl it returns to within about 0.5 degrees of the original heading the amount of friction can be considered within acceptable limits.

The liquid should be clear and free of bubbles.
Any optical system should be clean and correctly adjusted.
Azimuth reading devices and means of illumination should be found in working order.
The compass deviation book and the deviation card for each magnetic compass installed on the ship should also be checked.

(b) Gyro Compasses

The compass should be allowed to settle (it is necessary to use judgement in this respect).

If the compass is not settled during a reasonable period then verify that all repeaters remain in alignment with the reading of the master compass.

Check that the datum line on the base of all bearing repeaters is aligned with the fore and aft axis of the ship.

Ascertain the compass error by the best method that is practicable according to the circumstances. The settle point error should not exceed 0.75 × secant latitude (degrees). If the ship is not alongside make allowances for difficulty of measurement and for the allowed error of 0.5 degrees between the compass and bearing repeater.

Check that all repeaters used for navigation purposes are aligned to the gyro compass heading to within ± 0.5 degrees.

The mechanical parts of the bridge wing repeaters should be checked to ensure that they are in good condition and capable of operating satisfactorily.

(c) Radar

Overall performance should be checked by observation of the known echo response in the vicinity of the ship, due account being taken of the quality of the radar picture which can be obtained in the area.

The operation of the Performance Monitors should also be checked and, where possible, the monitor responses should be compared with the calibration record.

The alignment of the radar heading marker with the ship's fore and aft line should be checked.

Where provided interswitching facilities should be checked to ensure that the indicated heading marker is accurately aligned with all arrangements of units. If this is not the case, the Master should be advised and be requested to arrange re-alignment before the vessel departs.

(d) Automatic Radar Plotting Aids (ARPAs)

All ARPAs should be provided with test facilities or programmes to enable the integrity of the equipment to be checked. These facilities should be described in an Operating Manual. Use should be made of these test programmes or facilities in order to assess the performance of the ARPAs.

(e) Radio Direction Finder

It should be noted that the requirement for the calibration of the Radio Direction Finder to be verified annually is a condition to be complied with for the issue of a radiotelegraphy certificate.

A report of the check bearings taken annually in verification of the calibration curve should be retained onboard the vessel together with a record of the last date of calibration.

006 Signalling Apparatus

(a) Daylight Signalling Lamp

All ships over 150 G.T. engaged on international voyages are to be provided with an efficient daylight signalling lamp which is not solely dependent upon the ship's main source of electrical power.

(b) Sound Signals

All power-driven ships if 12 metres or more in length are to be provided with the following signals for use in restricted visibility:-

(i) An efficient bell hung in the forward part of the ship clear of all obstructions having a diameter of not less than 300mm at the mouth, except in ships under 20 metres but more than 12 metres in length, where a bell of not less than 200mm diameter is acceptable.

(ii) An efficient fog-horn sounded by mechanical means.

(iii) In ships of 100 metres of more in length, a gong for use at the after end of the ship.

(c) Daylight Shapes

(i) All ships are to carry three black ball shapes each not less than 600mm in diameter. Between sunrise and sunset three are to be displayed when the ship is aground, two when not under command, and one in the forward part of the ship when at anchor. When more than one are shown they are to be placed in a vertical line one above the other not less than 1.5 metres apart where they can best be seen.

(ii) All ships are to carry a black diamond shape at least 1.2 metres high and 600mm in diameter for display during daylight hours when the vessel is towing or being towed and the length of the tow exceeds 200 metres. The black diamond shape is also to be used in conjunction with two black balls to indicate the ship is restricted in her ability to manoeuvre.

007 Navigation Lights

Neither SOLAS 1974, nor the amendments thereto, have detailed requirements related to lights and sound signals to be carried on ships. The "link" is contained in the text of the Safety Equipment Certificate, which states "the ship was provided with navigation lights and shapes and means of making sound signals and distress signals in accordance with the provisions of the Regulations and the International Regulations for Preventing Collisions at Sea in force".

It follows therefore, that even if the flag state of the vessel is not a signatory to the International Regulations for Preventing Collisions at Sea 1972, (Colreg 1972) the requirements contained therein must be complied with as far as applicable, in order that a non-convention Safety Equipment Certificate, or a Statement of Compliance with SOLAS 1974 may be issued.

It is not a requirement of SOLAS 1974 or of the COLREG 1972 that two sets of navigation lights should be provided. The Regulations for Preventing Collisions require that "the Rules concerning lights shall be complied with from sunset to sunrise". (Rule 20 (b) refers).

Obviously the major obstacle to compliance with this requirement after navigation lights each certified as complying with COLREG 1972 have been fitted, will be either a power supply failure or a lamp failure. In the absence of specific National requirements, the generally accepted arrangement is to fit Duplex Type lights in the five steaming light positions and single anchor and N.U.C. lights.

SOLAS 1974 required electric navigation lights fitted on cargo ships of 5000 G.T. and upwards to also be powered from the emergency electrical source (Reg. 26 of Ch. II-I refers). The 1981

NOTES

Amendments require an emergency power supply to navigation lights on ships of 500 G.T. and upwards (Reg. 43 of Ch. II-1 refers). It is normal for the electric navigation lights on cargo vessels of less than 5000 G.T. to be similarly powered, especially if the vessel can operate following a failure of the main electrical supply.

During the Safety Equipment Survey it should be confirmed the lights required by COLREG 1972 are onboard and in efficient condition. Particular attention should be paid to the electrical connections, the lamp holder, lens and screening. Any audible and visual warnings of lamp failure located on the bridge should be checked for operational efficiency as should the emergency power supply.

Lights as detailed hereunder are required on all power driven vessels viz one or two masthead lights according to the length of the ship, two side lights, one stern light, two "not under command" lights and one or two anchor lights according to the ship's length. The lights to be carried by fishing vessels, ships engaged on underwater operations or surveying duties, sailing ships, pilot vessels, tugs, trawlers and other craft are also specified in the Collision Regulations. The length and breadth of a ship referred to in the Collision Regulations are the overall length and extreme breadth.

(a) Side Lights
On the port side a red light and on the starboard side a green light, both arranged to show an unbroken light from right ahead to 22.5 degrees abaft the beam and visible at a distance of 3 miles. The side lights should be positioned at or near the ship's side at a height not greater than three-quarters of the height of the foremast light above the uppermost continuous deck. They should not be so low as to be interferred with by deck lights nor should they be sited in front of the forward masthead light.

(b) Masthead Lights
On, or in front of, the foremast, or in the forward part of the ship, a white light arranged so as to show an unbroken light from right ahead to 22.5 degrees abaft the beam, on both sides, and visible at a distance of 6 miles. The height above the uppermost continuous deck is to be at least 6 metres but need not exceed 12 metres. Where the breadth of the ship is between 6 and 12 metres the height is to be not less than the breadth of the ship. On ships of 50 metres or more in length a second white light similar to the first, is to be placed on the main mast or other suitable position at least 4.5 metres higher than the forward light, such that, in all normal conditions of trim, the aft light will be seen over and apart from the forward light at a distance of 1,000 metres from the stem when viewed from sea level.
The horizontal separation of foremast and mainmast lights should be not less than one-half of the total length of the ship, but need not exceed 100 metres. The fore light should not be more than one-quarter of the ship's length from the stem.

(c) Stern Light
At the stern of the ship, as far aft as possible, a white light arranged to show an unbroken light from right astern to 22.5 degrees abaft the beam on both sides of the ship and visible at a distance of 3 miles.

(d) Anchor Lights
Ships of less than 50 metres in length, when at anchor, are to carry in the forward part of the vessel, where it can best be seen, a white light visible all round the horizon at a distance of at least 3 miles.
In ships of 50 metres or more in length a second white light similar to the first, is to be carried at or near the stern and both lights are to be visible at a distance of 3 miles. The forward light is to be at least 6 metres above the uppermost continuous deck and the after light not less than 4.5 metres lower than the forward light.

(e) Not Under Command Lights
In a position where they can best be seen, a power-driven vessel of length 20 metres or more, when not under command, is to carry two red lights in a vertical line, one above the other, not less than 2 metres apart, and not less than 4 metres above the hull except when a towing light is required. On vessels less than 20 metres in length the vertical separation shall be at least 1 metre and the lowest of the lights shall not be less than 2 metres above the gunwale except when a towing light is required.

(f) Screening of Sidelights
Side lanterns are to be provided with inboard screens painted matt black, with a screening chock at the forward end projecting outboard so as to prevent the light from being seen across the bows.

(g) Spare Electric Lamps
A stock of at least one complete set of spare electric lamps of the correct type is to be carried.

(h) Carriage of Oil Lanterns
In all ships, where the navigation lights are powered only by the ships main electric generating plant, provision is to be made to ensure that the ship can display the required lights in the event of complete failure of the main source of power. Compliance with this requirement can be achieved by providing a complete set of oil lanterns each certified for compliance with the 1972 Colregs, having the same characteristics as those applicable to electric lights. If, however, the ship is to berth at ports or oil installations, refineries, etc., where the lighting of oil lanterns is prohibited then a duplicate arrangement of electric lights and their source of power is required. The secondary power in new ships is to be supplied from the emergency source.

008 Pilot Ladders

All ships are to be provided with a pilot ladder complying with the following:-

(a) The ladder is to be efficient and is to be used only by officials and other authorised persons while the ship is arriving at or leaving a port, and for the safe embarkation and disembarkation of pilots.

(b) The pilot ladder is to be secured in a position clear of any possible discharges from the ship with each step resting firmly against the ship's side so that the pilot can gain convenient access to the ship after climbing not less than 1.5 metres and not more than 9 metres.

(c) A single length of ladder is to be used capable of reaching the water from the point of access to the ship due allowance being made for all conditions of loading and trim and an adverse list of 15 degrees. Whenever the distance from the water to the point of access to the ship exceeds 9 metres access from the pilot ladder to the ship is to be by means of an accommodation ladder or other equally safe and convenient means.

(d) The treads of the ladder are to be of hardwood not less than 48cm long 11.5cm wide and 2.5cm in depth, spaced not less than 30cm and not more than 38cm apart, and secured in such a manner that they will remain horizontal. The side ropes of the ladder are to consist of two manilla ropes each 6cm in circumference.

(e) Hardwood spreaders not less than 1.8 metres long are to be provided at intervals of not more than nine steps apart, to prevent the ladder twisting, the lowest spreader being the fifth step from the bottom.

(f) Two man-ropes not less than 6.5cm in circumference, properly secured to the ship, and a safety line are to be available and ready for use if required.

(g) Means are to be provided to enable the pilot ladder to be used on either side of the ship and to enable the pilot to pass safely and conveniently from the head of the ladder into the ship or on to the ship's deck and thence to the bridge.

(h) Lighting is to be provided at night so that the pilot ladder overside and the position where the pilot embarks or disem-

barks is adequately illuminated. A lifebuoy fitted with a self igniting light, and a heaving line, shall also be provided close by ready for immediate use.

(i) Where fenders or other projections make it impracticable for the pilot ladder steps to rest firmly against the ship's side, the arrangements will be specially considered.

009 Mechanical Pilot Hoists

Mechanical Pilot Hoists are required to be type approved. The design is to be such that the pilot can be embarked and disembarked in a safe manner and must include a safe access from the hoist to the deck and vice versa.

Single fall hoists are not acceptable. Mechanical Hoists, when fitted, are to be considered safety equipment survey items.

A pilot ladder complying with the applicable SOLAS requirements is to be kept on deck adjacent to any hoist and available for immediate use.

Every new hoist should be submitted to an overload test of 2.2 times the working load. During this test the load should be lowered a distance of not less than 5 metres.

An operating test of 10 per cent overload should be carried out after installation onboard, to check the attachments of the hoist and its satisfactory operation.

At Safety Equipment Renewal Surveys the hoist is required to be examined under working conditions.

The working load should be the sum of the weight of the ladder and falls in the fully lowered condition and the maximum number of persons which the hoist is designed to carry, the weight of each person being taken as 75kg.

010 Accommodation Ladders

Accommodation ladders which form part of the pilot boarding arrangements are considered to be surveyable items when dealing with Safety Equipment Renewal, Annual or Intermediate Surveys.

Accommodation ladders are to be constructed to an approved standard at least equivalent to International Standards Organisation (ISO) 5488-1979. After installation onboard a typical test would be to load each step with 75kg and the lower platform with 3 times 75kg and examine the ladder and its attachments for signs of distortion or distress, neither of which is acceptable.

At Renewal, Annual or Intermediate surveys the accommodation ladder, if it is part of the pilot boarding arrangements, should be verified in efficient working conditions. Particular attention should be paid to hidden parts of the structure the failure of which could cause an accident, e.g. centre pivot under upper landing platform.

011 Line-throwing Appliance

Every new and existing ship is required to carry a line-throwing appliance containing at least four lines and four projectiles, capable of throwing a line over a minimum distance of 230 metres with reasonable accuracy in calm weather. The rockets and cartridges are to be stamped indelibly with the date of manufacture and renewed when necessary. When line-throwing appliances require renewal of the rockets it should be ensured that any required igniters are also renewed. The appliance is to be contained in a water-resistant casing.

012 Ships' Distress Signals

Every new and existing ship is required to carry at least 12 parachute distress rocket signals, each capable of producing a single bright red star at a high altitude, its rate of fall being controlled by means of a parachute.

The rockets are to be packed in watertight containers, stowed in a dry place and stamped with the date of manufacture. Pyrotechnics are generally to be renewed three years after date of manufacture. However some national authorities have more specific requirements.

The Officer in charge should be reminded of the importance of the safe disposal of out-of-date pyrotechnics.

013 Survival Craft Portable Radio

An approved survival craft portable radio is to be provided and stowed in a protected, but readily accessible, position so as to be easily transported to any survival craft.

In ships where survival craft are widely separated the portable apparatus is to be stowed in the vicinity of the survival craft furthest from the ship's main transmitter.

The equipment is to comprise a transmitter, a receiver, an antenna and source of energy all enclosed in a buoyant watertight container able to withstand being dropped into the sea without damage.

This apparatus is not required if a fixed radiotelegraphy installation is installed in a lifeboat on each side of the ship or in a stern launched free fall lifeboat.

014 Emergency Position Indicating Radio Beacon (EPIRB)

A manually activated EPIRB is to be carried on each side of the ship such that they can be readily placed in any of the main survival craft, other than any liferaft required to be carried forward or aft.

015 Two Way Radiotelephone Apparatus

Two way radiotelephone equipment is required for communication between the ship, survival craft and rescue boats. Such equipment need not be supplied for each survival craft provided a minimum of three sets are available for ready use. The sets are to be maintained in a ready use condition and be of a type that can be used in an emergency by an unskilled person.

016 Location of Survival Craft and Rescue Boats

Before the 1983 Amendments entered into force, SOLAS 1974 required that a lifeboat or lifeboats able to accommodate 100 per cent of the persons carried on a cargo ship be provided on each side of the vessel. At least one motorlifeboat was required to be carried on dry cargo ships of 1600 G.T. and upwards, and at least one motorboat on each side on tankers of 1600 G.T. and upwards.

Liferafts of total capacity sufficient to accommodate 50 per cent of the persons carried on the vessel were also required. Generally these liferafts were located on the centreline of the vessel so as to be readily available in an emergency for use on either side of the ship on the deck on which they were stowed. In the event the liferaft/liferafts could not be easily moved to either side of the ship then 50 per cent liferaft escape capability was

NOTES

required on both the Port and Starboard sides.

An additional requirement was that a liferaft for at least six persons be located forward on vessels with a registered length of 150 metres or more and which had all accommodation located aft and no amidship superstructure.

The 1983 amendments to SOLAS 1974 now requires that on "new ships":-

(i) All lifeboats fitted on all cargo ships to be totally enclosed motor lifeboats capable of at least six knots. Lifeboats fitted on tankers, chemical and gas carriers are required to be fitted with external fire protection arrangements and internal life support systems as applicable.
(ii) Liferafts for 100 per cent of the persons carried on the vessel to be provided.
(iii) A liferaft able to accommodate at least six persons, to be located forward or aft if the above survival craft (lifeboats and liferafts) are located more than 100m from the stem or the stern.
(iv) An approved powered rescue boat able to accommodate at least six persons with five seated and one lying down be provided. The rescue boat is to be capable of being launched and recovered by davit, the recovery speed being not less than 0.3m/sec.

The following figures 1 to 5 illustrate the various configurations of survival and rescue craft as required by successive conventions and amendments.

At renewal surveys all lifeboats should be raised from their stowage positions to enable a thorough internal and external examination of the lifeboat to be carried out.

Portable air cases, if fitted, should be removed, carefully examined, and if considered necessary, tested. Total immersion in water should reveal any deficiencies in the air cases. The structure in way of the air cases should be carefully examined and care taken to ensure that the air cases are correctly re-fitted. Where "built-in" buoyancy is fitted, it is to be verified that the structure and integrity of the buoyancy remains efficient by an air test. It is recommended that the air be provided by means of a hand pump in association with a suitably calibrated U-Tube thus enabling small differences in pressure to be easily read. Any leakage can be detected by using soapy water applied to tank joints.

It is not normal to require the removal of solid buoyancy from those lifeboats where such material is fitted. However, in the event that visual inspection of the solid buoyancy gives cause for concern a partial opening up may be required. Any replacement material which it may be found necessary to fit, should be of an accepted oil resistant type which is also chemically compatible with the original material.

LIFEBOATS AND LIFERAFTS (Actual Convention Requirements Shown)

Lifeboats minimum length 7.3 m (24 ft) except in special circumstances, but in no case less than 4.9 m (16 ft).

Liferafts (rigid and inflatable) are not to exceed 180 kgs (400 lbs) total weight if they are launched by hand and the carring capacity of each raft is to be not less than six and not more than 25 persons.

Tanker and Dry cargo 500 G.T. under 1600 G.T.

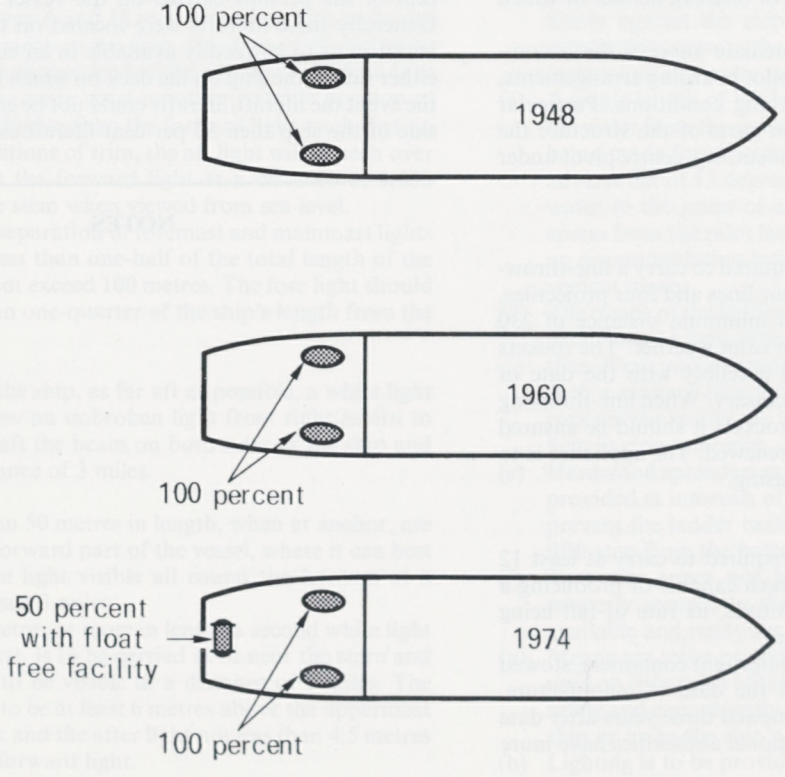


Fig 1

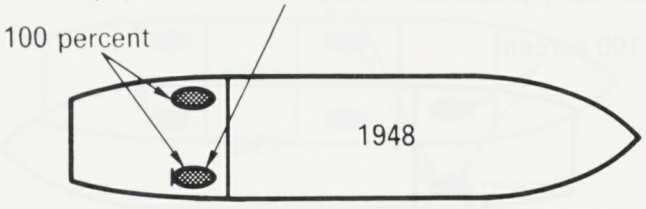
LIFEBOATS AND LIFERAFTS (Actual Convention Requirements Shown)

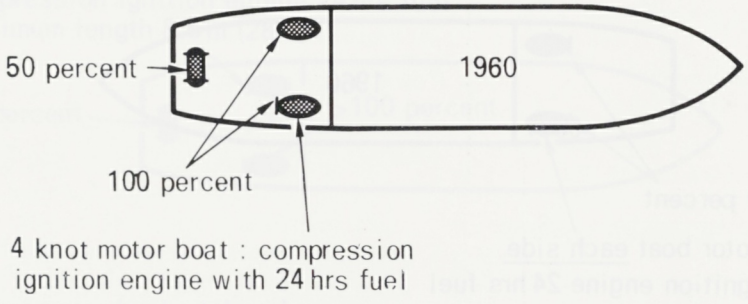
Dry cargo 1600 G.T. and upwards

Class A motor boat : compression ignition engine
6 knots with 24 hrs fuel, or

Class B motor boat : petrol engine 4 knots
with adequate fuel, or

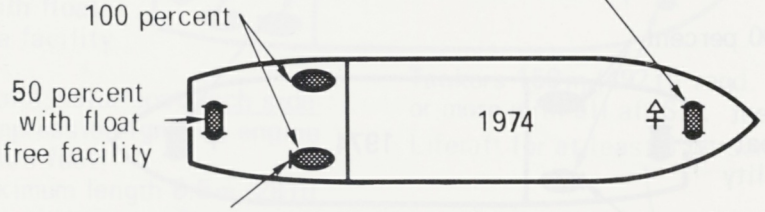
Mechanically propelled lifeboat





4 knot motor boat : compression
ignition engine with 24 hrs fuel

Liferaft forward:all cargo ships
150m (492ft) regd. length or more
with all aft superstructure (raft to
accommodate at least 6 persons)



4 knot motor boat : compression ignition engine with 24 hrs fuel

The liferaft forward may be securely lashed

Fig 2

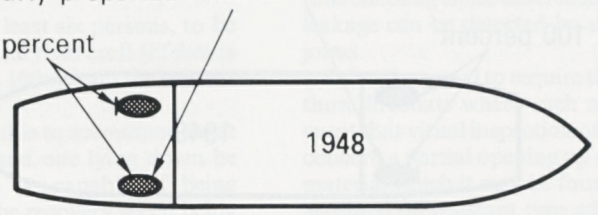
LIFEBOATS AND LIFERAFTS (Actual Convention Requirements Shown)

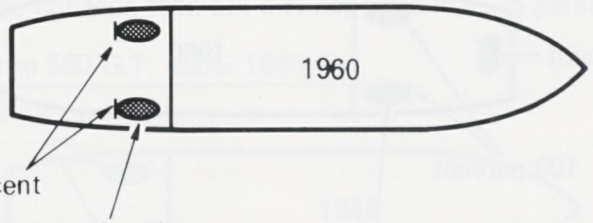
Tanker 1600 G.T. below 3000 G.T.

Class A motor boat : compression ignition engine
6 knots with 24 hrs fuel, or

Class B motor boat : petrol engine 4 knots
with adequate fuel, or

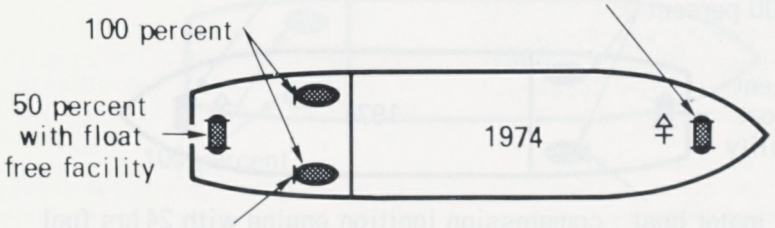
Mechanically propelled lifeboat





6 knot motor boat each side
compression ignition engine 24 hrs fuel

Liferaft forward : all tankers 150 m (492 ft)
regd. length or more with all aft S.S.
(Raft to accommodate at least 6 persons)



6 knot motor boat each side compression ignition engine 24 hrs fuel

† The liferaft forward may be securely lashed

Fig 3

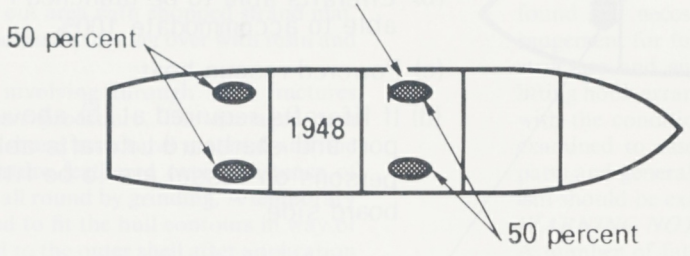
LIFEBOATS AND LIFERAFTS (Actual Convention Requirements Shown ⬭ 🧍)

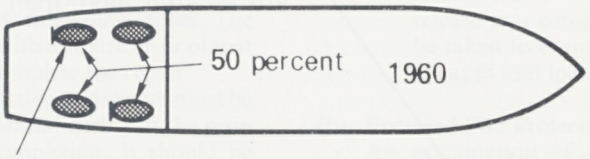
Tanker 3000 G.T. and upwards

Class A motor boat : compression ignition enging
6 knots with 24 hrs fuel, or

Class B motor boat : petrol engine 4 knots
with adequate fuel, or

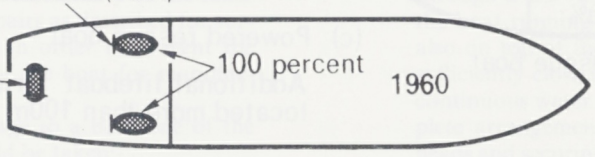
Mechanically propelled lifeboat





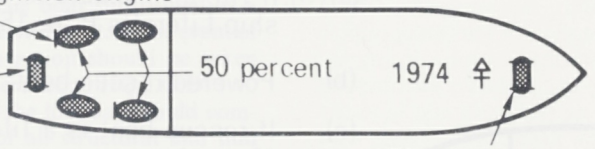
6 knot motor boat each side : compression ignition engine 24 hrs fuel

6 knot motor boat each side :
compression ignition engine 24 hrs fuel
Maximum length 8.5 m (28 ft)



6 knot motor boat each side :
compression ignition engine
24 hrs fuel

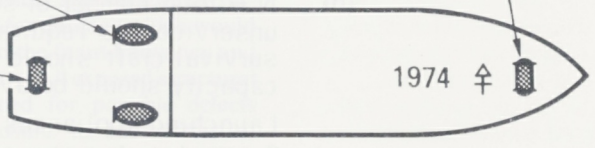
50 percent
with float
free facility



Tankers 150 m (492 ft) regd. length
or more with all aft S.S.
Liferaft for at least 6 persons

6 knot motor boat each side :
compression ignition engine
24 hrs fuel
Maximum length 8.5 m (28 ft)

50 percent
with float
free facility



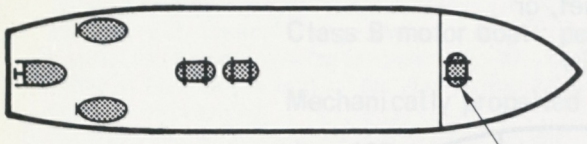
‡ The liferaft forward may be securely lashed

Fig 4

Requirements of amended Ch. 3 to SOLAS 1974 Which apply to cargo ships

A

Cargo ships(300%)



Powered rescue boat

Min. 2 E.P.I.R.B.
one port one starboard

(a) P & S totally enclosed motor lifeboat for 100%

On tankers including chemical and gas carriers carrying flamable cargoes
Lifeboats shall be motor totally enclosed and fire retardant

On tankers carrying cargoes emitting toxic vapours or gases Lifeboats **to be motor totally enclosed fire retardant and fitted with self contained air support system**

(b) Liferafts able to be launched P & S which in aggregate are able to accommodate 100%

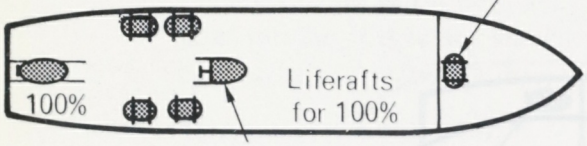
(c) Powered rescue boat

(d) If liferafts required at (b) above are **not** able to be launched port and starboard Liferafts able to accommodate 100% persons on vessel are to be fitted on both port and starboard side

Additional liferaft forward or aft if 'Rule survival craft' are located more than 100m from stern or stem

or **B**

300%



Powered rescue boat

(a) A lifeboat or lifeboats able to be launched by freefall over stern of ship able to accommodate 100%

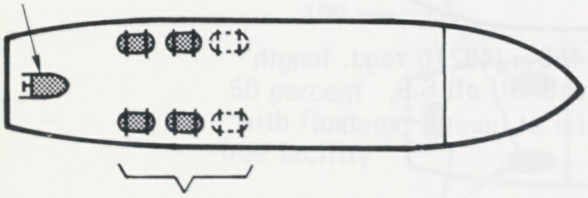
(b) Liferafts P & S for 100% **served by launching appliances** on at least one side of the ship

(c) Powered rescue boat

Additional lifeboat forward to 'Rule' survival craft are located more than 100m from the stem

Cargo ships less than 85m length(not tankers)

Powered rescue boat



150% port and starboard
See (a)(ii) above

(a)(i) Liferafts port for 100% Liferafts stbd for 100% Able to be launched from either side of ship.

(a)(ii) If liferafts **unable** to be transfered to either side of the ship Liferafts P for 150% and liferafts S for 150%

(b) Powered rescue boat

(c) If rescue boat is a lifeboat in compliance with Regulation 43 or 44 it may be included in the required aggregate capacity providing the total capacity available on either side of the ship is 150% of the total number of persons on the ship

(d) N = total number of survival craft. With one craft unserviceable requirement is that capacity of available survival craft should be such that 100% survival craft capacity should be available port and starboard

Launching appliances required for all craft survival **except** Survival craft with a mass of less than 185Kg which are boarded from a position on deck less than 4,5m above the waterline in the lightest seagoing condition

Note: 25 persons raft approx. 180 Kg

A throw overboard or portable liferaft and its contents is not to exceed 185Kg mass

Fig 5

The following guidance notes, related to lifeboat surveys of specific construction types, do not provide an exhaustive list of defects and/or damages. It should be remembered that the ultimate responsibility is with the Surveyor to confirm lifeboats and their equipment remain efficient.

(a) Glass Reinforced Plastic Lifeboats

Lifeboats should be lifted clear of stowage chocks and the shell exterior cleaned for examination. The hull gelcoat should be visually examined for evidence of cracking or crazing, contact damage and general deterioration (particularly in way of bearing surfaces) and tested for delamination by light sounding. Surface defects should be repaired by grinding the gelcoat back to sound material, reinforcing the ground out area with chopped strand mat, or a mat/resin mix, as necessary, facing over with resin and fairing off when cured.

More serious defects involving through shell fractures require a different repair procedure. The damaged area should be cut back to sound structural material and the inner edges of the aperture feathered over a distance of approximately 150mm all round by grinding. A temporary mould should be shaped to fit the hull contours in way of the damage and secured to the outer shell after application of a release agent. The gelcoat resin should then be applied and the laminate built up to at least the original shell thickness with chopped strand mat. Each layer should be impregnated with resin, by means of stippling with a clean paintbrush, and then consolidated with a metal roller. The complete area should be overlaid with an extra layer of mat for additional reinforcement to complete the repair.

When carrying out repairs local heating and shelter must be provided in order to assist the essential curing of the resin both during repairs and after completion. It should be allowed to remain in place until a reasonable degree of cure has been effected.

It should be noted that major repairs of through shell damage in way of built-in foam buoyancy cannot be carried out in this manner due to the inaccessability of the inner face. Only temporary external repairs as described for surface defects, can be carried out in order to prevent the ingress of water until removal of the boat for manufacturers repair.

In the event of substantial damage to a boat one of the following courses of action should be taken:-

(i) Replacement of lifeboat if damage is not repairable;

(ii) Removal to a G.R.P. works for professional repair. If it is not possible to return the lifeboat to service before the ship sails then liferafts totalling a similar capacity may be substituted as a temporary alternative or liferafts and a powered rescue boat substituted as a temporary alternative for a motor boat. In the event of this being contemplated no action should be taken without immediate prior reference to HQ/I.C.D.

An internal examination of the lifeboat should commence with an inspection of all structural and hull stiffening members. The shell should be examined throughout for evidence of stress and impact fractures particularly in way of gunwale, keel and hull bottom. The bonding of the buoyancy casing to the hull should be inspected for signs of failure, (if necessary apply a suitable air test) and the vertical and horizontal surfaces examined, particularly for damage which would allow water to penetrate into the foam buoyancy and possibly cause it to disintegrate. All exposed structural laminate should be examined for possible defects caused by prolonged exposure to the effects of weather, the most serious of which is leaching. This will reveal itself in areas from which the resin has been eroded thus leaving the reinforcing mat exposed and vulnerable to further damage. Areas where this has occurred should be ground back to sound resinated material, reinforced as necessary with well consolidated chopped strand mat and treated with a thick resin overlay. The area in way of bonding failure should be abraded and new chopped strand mat laid in, each laminate overlapping by 50mm.

All internally fitted components should be examined for security and condition with particular attention being paid to through hull connections. Wood components, thwarts, floorboards and packing pieces etc., should be tested for decay.

Hull structure should be examined at the positions where tie bars are secured to the hull for any evidence of working or stress cracking. Any structural defects found will necessitate the removal of the hook arrangement for further examination of the underlying structure and subsequent repairs as necessary. The lifting hook arrangement and it's attachment together with the condition of the lifeboat in way should be examined to assess the condition of it's component parts and general security. The hook release mechanism should be examined and tested.

WARNING NOTE

A number of fatalities have occurred due to the accidental 'on-load' release of lifeboats at routine maintenance and examination. Release mechanisms are often locked with only one safety pin which can easily be inadvertently removed leaving the simultaneous release gear completely open. Strict precautions must be taken to ensure that release mechanisms are fully engaged and locked before boarding any lifeboat.

(b) Enclosed Fire Protected Lifeboats

An examination of the hull should be undertaken as previously described for GRP lifeboats together with the following additional items:-

(i) The Spray System

A main engine operated pump circulates water through a sea valve to a piping system fitted around the boat running under each gunwale outboard and also on top of the canopy. Spray heads are fitted at sufficiently close intervals to provide a complete and continuous water cover of hull and canopy. The complete arrangement of seacock, pump, piping, spray heads and securing clips and bolts should be examined for condition and the system's operation tested if

NOTES

considered necessary.

(ii) Air Life Support System

In order to provide a completely independent short duration life support system within the boat during launch and breakaway under severe fire or toxic atmospheric conditions a compressed air installation consisting of air cylinders and a piping and discharge arrangement operating through a control valve is fitted. As well as providing breathable air for the boats' occupants the cylinders also supply sufficient air to maintain the engine at full power for the duration of the complete close down of the lifeboat.

The air cylinders should be examined for capacity to ensure that sufficient air is contained to supply the boat for the required duration of eight to ten minutes. A contents gauge should be fitted which will allow the cylinder contents to be verified without loss of air. The complete system should be checked for condition and security of stowage.

The GRP canopy should be examined externally and internally for evidence of deterioration or damage as for the hull. The chopped strand mat joint bonding the canopy to the hull should be inspected for signs of failure and the through bolts for condition and security.

The steering arrangement, which is usually wheel operated from the helmsman's position, should be examined for condition and tested hard over to port and starboard. The connection to the rudderhead should be inspected and the rudder gland checked for watertightness. Where steering cables are fed through conduit sufficient cable should be seen to determine the overall condition.

The engine mounting frame, which is sometimes flexibly secured to the side bench fronts, should be examined for condition and security and the stern gland arrangement inspected for undue leakage. Engine securing bolts and all other connections should also be examined. Where engine keel cooling systems are fitted special attention should be given to through fastenings.

If the hull, or repairs, are to be painted only polyurethane based paints should be used.

(c) Steel Lifeboats

Boats constructed in this material fall into two main groups; all-steel boats where other materials are kept to a minimum and steel hulled boats with a basically wooden outfit.

It is perhaps to state the obvious to say that the commonest defect in steel boats is corrosion. All steel structure in lifeboats (with the possible exception of the lifting hooks) should be galvanised after all forming, assembling, riveting etc., is completed. However, this is not always possible and the use of an appropriate painting system should be regarded as the minimum acceptable protection to bare steel resulting from repairs or alterations. Signs of rusting are generally obvious and easily obliterated by cleaning off and applying a coat of paint.

The first action when presented with a steel lifeboat for survey should be to insist on all portable gear, gratings, side benches, cleading etc. being removed so far as it is reasonably possible in order to leave the steel structure exposed. Manhole and inspection covers to peak and side buoyancy tanks where these are fitted should also be removed.

Having stripped the hull out as far as possible, typical trouble spots should be specially examined. Such examination should include wire brushing, chipping, hammering or any other suitable treatment to remove painted scale, rust flakes etc. These areas include:-

(i) The lower portions of all vertical structures, peak bulkheads, cleading or side tank bulkheads and anywhere moisture, condensation, bilge water etc., can lie undetected.

(ii) The bottom of the boat especially in way of waterways, adjacent to the keel structure, vertical portions of floors, frame flanges, around drain plugs and other fittings, under engine and fuel tanks etc.

(iii) All places where timber is in contact with metal surfaces, e.g. thwart ends, under side bench timbers, floor grating bearers etc., and anywhere where timber could hold moisture in contact with the steel. Special attention should be given to davit chocks in this respect. Many steel boats are built with doublers in way of these chocks.

(iv) Hollow sections, pipes etc., at the gunwale, turn of bilge and, occasionally at stem and stern posts are subject to internal condensation and therefore liable to internal corrosion which is not normally obvious externally until well advanced. These items should be subject to a most careful examination and hammer test.

(v) Portable buoyancy tanks should always be removed and tested (this enables boat's side structure to be examined). Such tanks are normally of galvanised steel sheet in steel lifeboats and any corrosion or other damage to the tanks themselves frequently means condemning that tank and obtaining a replacement. All tanks should be tested for airtightness before being replaced in the boat. This can be done by immersion in a tank of water or by an air pressure test. Air pressure of 0.035kg/cm^2 is quite adequate for this purpose. All wooden grounds, brackets etc., for securing the tanks should be checked for tightness of fit to prevent tank movement and chafing of the galvanised surfaces.

(d) Aluminium Lifeboats

In general, the remarks concerning steel lifeboats can also be applied to aluminium boats of which two main types are encountered; all aluminium boats in which other materials are limited to a minimum and aluminium hulled boats with a basically wooden outfit. The more usual defects found in aluminium lifeboats are due to corrosion or impact damages. Bare aluminium boats are occasionally met with. More usually, the aluminium has been degreased, etch primed and a top coat of zinc oxide based paint applied. It should be noted that lead or copper based paints should not be used on aluminium items. When presented with an aluminium boat for survey, all loose and portable items should be removed, including manholes and inspection covers to peak spaces and buoyancy tanks (if these are fitted). Corrosion, if present, is generally obvious since pits or holes are readily formed.

The same areas enumerated for particular attention in steel lifeboats should receive similar attention in aluminium boats.

Aluminium is particularly susceptible to chemical corrosion at bi-metallic joints and in way of water drips from non aluminium fittings. Thus particular attention should be paid to the regions below the engine, propeller shaft, stern gland, lift hooks and associated quick release gear leads, etc.

Rivets in aluminium boats are subject to work hardening during construction and often the heads can become detached from the shank. Care should be taken to ensure that all the heads are intact by scraping a hammer internally along the line of rivet heads.

(e) Wooden Lifeboats

The main defects likely to be encountered in a wooden lifeboat, other than obvious damages, are due to deterioration of the timber, fastenings or the timber in way of fasten-

ings. Wooden lifeboats are frequently stowed in their davits with some water in them to help maintain watertightness. On survey any water should be drained and mopped up and all portable structure and fittings, including buoyancy tanks, should be removed. The following potential trouble spots should be given special attention:-

(i) The keel, garboards and associated structure should be examined from within the boat and from outside for signs of rot, infestation, loose fastenings, split planking, nail sickness i.e. deterioration of the planking locally in way of nail fastenings.

(ii) The bottom of the boat generally, but particularly where the surface of bilge water has reached should be examined for rot, cracks etc.

(iii) The bottom edges of vertical structures, peak bulkheads, cleading etc., are particularly liable to rot and fungal attack due to condensation, moisture etc., collecting in poorly ventilated spaces.

(iv) Some wooden lifeboats are fitted with foam buoyancy which should be removed, if reasonably practicable, to ascertain the state of the foam. Portable buoyancy tanks should be removed and tested by immersion in a tank of water, or by air pressure. These tanks are generally of copper or 'yellow metal' with soldered joints. An air test pressure of 0.035kg/cm^2 should not be exceeded. Test holes should be soldered up on completion of the test. Care should be taken to avoid sudden extremes of temperature since a sudden blaze of hot sunshine is capable of 'blowing' a soldered tank left out in the open.

(v) Normally inaccessible or concealed items should be specially examined for rot, infestation, loose fastenings etc. Such places include risings, thwart ends, undersides of breast hooks etc. Split planks should be cropped and renewed as necessary. Copper or brass fastenings can usually, unless badly corroded, be hardened up. Steel bolts (e.g. in lifting hook foundations) may need to be driven out and replaced by galvanised bolts, possibly of a slightly increased diameter if the wood in way has been bruised. All new timber used for repairs should, as far as possible, be of a similar type to that being replaced and be dry, free from knots, shakes, resin inclusions and other defects. All plank landings etc., should be bedded with a suitable compound and the whole repair finished with an appropriate paint system.

In clinker-built lifeboats, no attempt to caulk leaking overlaps of seams should ever be contemplated. If the boat is weighted and left in the sea, for a period of time these seams will normally take up and become tight.

GRP should never be used to repair a wooden lifeboat since the strength of such a repair would be dubious and furthermore would lead to rotting of the wood at the joining face which would be difficult to detect on subsequent surveys.

(f) Lifeboat Outfit (General)

All loose gear should be checked for quantity against the form S.E.1 and also for condition and continued efficiency. Mast and sails, if fitted, should be rigged, the sea anchor and line run out, all lines and ropes checked (including festoon and gunwale to gunwale grablines), rudder and tiller should be shipped and operated, rowlocks checked for freedom of rotation, engine run ahead and astern, hand propelling gear operated, first aid kit checked to see that the seals are unbroken, pyrotechnics dates should be checked, electric torch batteries verified and fuel and fresh water tanks checked for capacity and content.

It is emphasized again, that no set of notes, such as this, can be expected to provide an exhaustive list of points to be checked. It remains the responsibility of the Surveyor concerned to ensure that before issue of a certificate of any form, each lifeboat, is complete with all its ancillary gear and equipment.

017 Simultaneous Release Mechanism

It is a requirement of the 1983 Amendments so SOLAS 1974 that lifeboats launched by the use of falls, are also fitted with a mechanism which is arranged to ensure that all hooks are released simultaneously.

The mechanism is to have two release capabilities viz:-

(i) the normal "off-load" release capability which will release the lifeboat when it is waterborne or there is "no-load" on the hooks; and

(ii) an "on-load" release capability which will release the lifeboat when there is a load on the hooks. This second release capability is to be arranged so that the lifeboat can be released under any conditions of loading from "no-load" with the lifeboat waterborne to a load of 1.1 times the total mass of the lifeboat when loaded with its full complement of persons and equipment. This second release capability is to be adequately protected against accidental or premature operation.

The primary aim in fitting these particular types of release equipment is to facilitate the safe release of the rafts and boats from the davit falls during an evacuation, especially in heavy weather conditions.

Whilst this type of release equipment represents a great technical advance over the traditional hook, which has been used for so many years, it is also much more complex. Consequently, to ensure that it will always function efficiently, it must be properly adjusted, regularly maintained and correctly operated at all times. Of particular importance is the need to ensure that the correct design of ring or shackle is being used to connect the release equipment to the davit falls. Failure to attend to any of these factors could cause a malfunction of the release equipment, resulting in the raft or boat being released prematurely or, alternatively, being retained on the falls when waterborne, with potentially disastrous results in either case.

Unfortunately several serious accidents involving the use of these release mechanisms have been recorded. These include:-

(i) premature release of lifeboats from the falls; causing death and serious injuries to the occupants and extensive damage to the boats;

(ii) retention of a lifeboat on the falls when waterborne; the occupants were uninjured but great difficulties were experienced in releasing the boat;

NOTES

(iii) premature release of davit launched liferafts from the falls; causing loss of confidence to members of the crew witnessing the launches and also damage to the rafts.

These accidents occurred during drills and tests, however, the added seriousness of any such incident occurring during a genuine abandonment will be readily appreciated.

Investigation of the incidents showed that the primary cause was due to the equipment being inadequately maintained, improperly adjusted, or incorrectly operated. Attention is therefore drawn to these particular problems and especially the need to ensure that crew members are given full and regular training in the correct operation of this type of equipment. Furthermore it is essential for the equipment to be adjusted and maintained in strict accordance with the manufacturer's instructions and tested at least once every three months as required by Reg 18 of Chapter III of 1983 Amendments to SOLAS 1974. Such tests should verify:-

(i) the operation of automatic release hooks for liferafts by suspending an appropriate weight; setting the hook and then lowering the weight to the deck where it should be automatically released;

(ii) the operation of "on-load" disengaging gear and "off-load" release mechanisms by lowering the boat into the water and then pulling on the control lever after which the hooks should open. This equipment should never be tested whilst the boat is hanging in the davits.

Regular servicing and proof testing of release equipment is now recommended when it is fitted on any ship, the building of which commenced on or after the 1 July 1986, and these procedures are also strongly recommended when such equipment is fitted on any older ship. For automatic release hooks for rafts, servicing and proof testing is to be conducted at intervals not exceeding 2 and 5 years respectively. For "on-load" disengaging gear and "off-load" release mechanisms for boats; such procedures are to be conducted at intervals not exceeding 5 years.

It is considered appropriate to state that these mechanisms need to be of an approved type which has been satisfactorily prototype tested to 6 times the safe working load. In the case of initial surveys this should be verified by the attending surveyor.

EXPLANATORY NOTE

"Off-load" release mechanisms, fitted in lifeboats and the automatic release hooks used for liferafts, are designed to be operated (opened) when the load applied to them is removed, i.e. when the boat or raft has been lowered and becomes waterborne.

"On-load" disengaging gear, fitted in lifeboats and rescue boats, is designed to be operated (opened) when the boat has been lowered and becomes waterborne, whether or not a load is being applied to it by the action of the ship or the sea.

Figures 6 and 7 show typical simultaneous release arrangements.

018 Lifeboat Launching Appliances

The requirements of successive Conventions differ considerably with respect to these items of equipment and the following guidance highlights the main differences and survey requirements.

SOLAS 1974 required that:-

(a) Each lifeboat should be attached to a separate set of davits.

(b) Each lifeboat should be positioned as close to the accommodation and services spaces as possible.

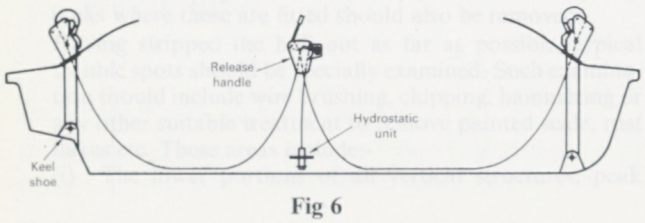


Fig 6

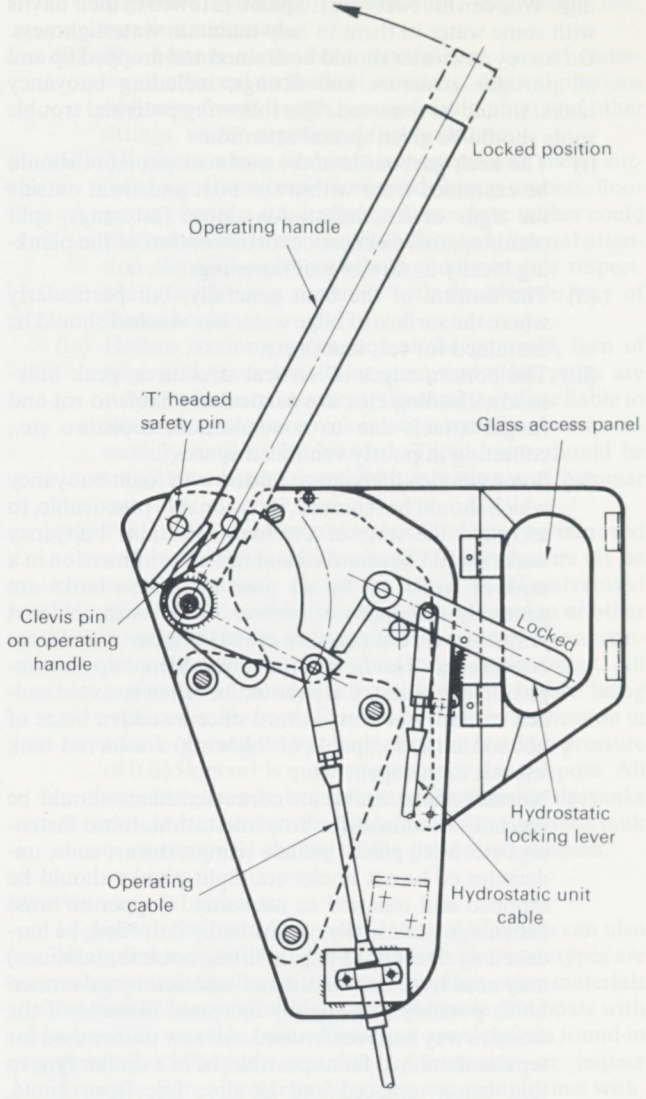


Fig 7

(c) Due regard should be given to the location of the lifeboat relative to the propellor of the ship.

(d) In new tankers of 1,600 G.T. and upwards, new whale factory, fish processing and canning factory ships the davits were to be of the gravity type. In other new ships, gravity type davits were to be fitted, except that where the lifeboats weighted not more than 2.25 tons (2300kg.) in their turning out conditions, davits of the luffing type could be installed.

It was usual to require that:-

(i) All gravity davits had a positive turning out moment during the whole of the davit travel from the inboard to the outboard position with the ship upright and also when the ship listed to any angle up to and including 25 degrees either way from upright.

(ii) The operating gear of all luffing type davits were of sufficient power to ensure that the fully equipped lifeboats manned by a launching crew of two persons could be turned out against a list of at least 15 degrees.

(e) Davits, falls, blocks and other associated lowering gear were of such strength that the lifeboat with its full equipment and manned by a launching crew of not less than two persons could be turned out and safely lowered to the water from the embarkation position with its full complement of persons, with the ship trimmed up to 10 degrees and listed 15 degrees either way. The weight of each person was taken at 165lb (75kg.).

(f) Lifeboats attached to gravity type davits were to be served by wire falls and winches. The breaking tensile load of each wire rope fall was to be not less than six times the maximum load on the wire when lowering, hoisting or stowing. The winch to be fitted with a drum for each wire, so as to keep the two falls separate, a hand brake, and in addition an automatic brake was to be provided for controlling the lowering speed of the boat. The hand brake was to have a weighted hand control lever which, when lifted, allowed the winch to rotate and when released operated the brake effectively without having to apply additional pressure. The automatic brake was adjusted to give a lowering speed of between 60 and 120ft. (18 to 36m.) per minute.

(g) Lifeboats attached to luffing type davits were to be served with wire rope falls and winches under the same provisions as for gravity davits except that the Regulations allowed for manila falls, where the Administration was satisfied that such falls were adequate. Details of all lifeboat launching arrangements were to be submitted for approval.

(h) Means were provided for bringing the lifeboats against the ship's side (Tricing pendant) and holding them there (Bowsing tackle) so that persons were safely embarked.

(i) Skates or other suitable means were to be provided to facilitate launching the lifeboats against a maximum list of 15 degrees.

(j) At least two lifelines (man ropes) were required to be fitted to each davit span wire, long enough, together with the lifeboat falls to reach the water with the ship listed 15 degrees either way and at its lightest sea going draught.

(k) Where davit launched liferafts were fitted the launching arrangements provided were also required to be of an approved type.

It should be noted that SOLAS 1974 did not require simultaneous release of the lifeboat from both falls, nor did it contain any requirement related to the recovery capability of lifeboat or liferaft launching appliances.

The revised CH. III of the 1983 Amendments to SOLAS 1974 considers lifeboats and liferafts as survival craft. A rescue boat is not considered to be a survival craft unless it is a lifeboat designated as a rescue boat in which case it, together with its launching and recovery appliance, is to fully satisfy all requirements applicable to both lifeboat and rescue boat. The performance characteristics required to be complied with by "launching appliances" are dependent on the type of survival craft or rescue boat with which they are to be used.

Lifeboat launching appliances are now required to be able to:-

(a) Launch the lifeboat fully equipped and loaded with the full complement of persons which it is certified to carry from the STOWED position on cargo ships or embarkation deck of passenger ships direct to the water, with the ship at its lightest sea going draft, trimmed up to 10 degrees and with list up to 20 degrees either way.

(b) Launch the lifeboat under the conditions specified at (a) above WITHOUT persons in the lifeboat.

(c) In the case of, oil tankers, chemical carriers and gas carriers launch the lifeboat at the final angle of heel after damage (if this exceeds 20 degrees) on the lower side of the ship, under the remaining conditions specified in (a) and (b) above.

(d) The launching appliance shall not depend on any means other than gravity or stored mechanical power which is independant of the ships' power supplies, to launch the lifeboat it serves in the fully loaded and equipped condition and also in the light condition.

(e) The launching appliance shall be so arranged that it is operable both from within the survival craft and from a position on the ship's deck. The survival craft shall be visible during launching to the person on the deck.

(f) The winch brakes of a launching appliance shall be of sufficient strength to withstand:-

  (a) a static test with a proof load of not less than 1.5 times the maximum working load and

  (b) a dynamic test with a proof load of not less than 1.1 times the maximum working load at the maximum lowering speed.

(g) The launching appliance and its attachments, other than winch brakes shall be of sufficient strength to withstand a static proof load on test of not less than 2.2 times the maximum working load.

(h) Structural members and all blocks, falls, pad eyes, links, fastenings and all other fittings used in connection with launching equipment shall be designed with not less than a minimum factor of safety on the basis of the maximum working load assigned and the ultimate strength of the material used for construction. A minimum factor of safety of 4.5 shall be applied to all davit and winch structural members, and a minimum factor of safety of 6 shall be applied to falls, suspension chains, links and blocks.

(i) A lifeboat launching appliance shall be capable of RECOVERING the lifeboat with its "crew."

(j) A lifeboat launching appliance shall be so arranged that all persons can board the lifeboat in not more than 3 minutes after the order to board is given.

(k) Falls shall be of rotation-resistant and corrosion resistant steel wire rope.

(l) An efficient hand gear shall be provided for recovery of each lifeboat.

(m) Where davit arms are recovered by power, safety devices (e.g. limit switches) shall be fitted to each arm which automatically cut off the power, before the davit arms reach the stops, in order to avoid overstressing the falls or davits, unless the motor is designed to prevent such overstressing.

(n) The minimum lowering speed for a lifeboat is obtained from the formula:-

  $S = 0.4 + (0.02 \times H)$.

  where S = speed of lowering in metres per second.

  H = height in metres from the davit head to the waterline at the lightest seagoing condition.

(o) The maximum lowering speed shall be established by the Administration. Means shall be incorporated in the appliance to ensure that the maximum speed is not exceeded.

(p) Every lifeboat launching appliance shall be fitted with brakes capable of stopping the descent of the lifeboat and holding it secure when loaded with its full complement of persons and equipment.

  Manual brakes shall be so arranged that the brake is always applied unless the operator, or a mechanism activated by

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the operator, holds the brake control in the "OFF" position.

For "Freefall" lifeboat launching appliances, in addition to compliance with paragraphs (a) to (j) inclusive the launching appliance is to be arranged so that:-

(i) Excessive forces are not experienced by the occupants of the freefall lifeboat during launching.

(ii) The angle and length of the launching ramp are such to ensure that the survival craft will effectively clear the ship.

(iii) It is effectively protected against corrosion at all times and so constructed to prevent during launching incendive friction or impact sparking.

For evacuation slides the launching and embarkation arrangements should satisfy the applicable requirements of paragraph (a) to (j) inclusive and in addition, be capable of being deployed by one person at the embarkation station and of being used in high winds and in a seaway.

Davits will have initially been subjected to stringent examinations and tests during construction and defects, other than damages due to collision, heavy weather, etc., are not commonly found in the main davit structure. There are, however, three main causes of defects in davits, namely corrosion, wear and lack of or misuse of paint. It is not unusual to discover that the careless application of too much paint to the davit has resulted in grease nipples and lubrication points becoming obstructed and pins, sheaves etc. being rendered inoperable. Defects in the main structural items such as the arm, stool and/or fixed trackway can be dealt with as for any other item of ship's structure.

At surveys davits should be run or turned out to bring the boat to the embarkation position, or the upper deck, if the boat is able to be boarded and launched from the stowed position. It is advisable, however, to carry out as much of the survey as is practicable before such an operational test, in the event that a major hidden weakness exists. The boats should be lowered, from the embarkation position or upper deck level, a procedure which will indicate freedom or friction in the various moving parts and any movement in the attachments to the ship. At this time special attention should be given to the following:

(i) Movement in the deck foundations, visible from either above or below the deck. Water is frequently allowed to lie in these areas giving rise to corrosion of the seatings and holding down bolts. A thick coat of paint is no guarantee that corrosion is not taking place underneath. In some older ships the davits are often situated on wood sheathed decks, in which case the condition of the deck in way should be carefully examined, particularly the underside – by hammer test if the condition is suspect.

(ii) Movement in the upper foundations of trackways or in stools which are secured to deckhouse structure.

(iii) Pivot pins and axles should be carefully examined for indications of slackness due to wear, corrosion, or seizing up due to misuse of paint. All greasing points should be checked, cleaned and recharged as necessary.

(iv) All fall wire sheaves should be confirmed as being free running, and specially examined for corrosion or fouling up of the grooves due to lack of maintenance, or by misuse of paint. It should be confirmed that wire falls remain pliable and well greased, particular attention being given to parts that are normally out of sight for example the security of the end attachments. It is at present a requirement to turn the falls end for end after $2\frac{1}{2}$ years, and to renew the falls after 5 years unless damage or excessive deterioration calls for earlier renewal.

(v) All rollers and guides in trackway type davits should be similarly checked for free running, fouling up, corrosion or unevenness.

(vi) Davit head horns should be specially examined for wear and connections to the davit head should be inspected for cracks or corrosion and repaired as necessary.

(vii) The functioning of all limit switches should be checked, any excess paint being removed and corrosion dealt with.

(viii) The end connections of the horizontal stays between sets of davits should be examined for soundness during operation. Any movement will have an adverse effect on the condition of the deck foundations.

(ix) Lifeboat winches are as essential to lifeboats as the davits themselves: therefore both hand and powered units should be subjected to an equally thorough examination. Winches are not always approved for materials or construction, nor examined during manufacture: therefore it will be necessary on many occasions to open up, overhaul, reassemble and test as for any other lifting gear, together with a close examination of the holding down bolts. Mention might also be made at this point of the necessity for closely examining blocks, shackles, swivels, clips and securing devices in association with any annealing and retesting after repairs which may, as in the case of cargo gear, be found necessary. Particularly, this requirement may apply to deck snatch blocks for sharp leads to winch barrels from the davits. The operation of the governor should be verified, care being taken to ensure that the hand brake is completely clear of the drum when checking. This can be dealt with during the lowering test.

(x) The most susceptible components in any davit system are the fall wires which should, if well maintained, be pliable and well greased. They should be run out to the furthest possible extent and checked for length, terminal connections checked for soundness, the wire remaining on the winch drum or normally positioned around the sheaves in the stowed position, being also carefully examined for corrosion, wear, twisted or broken strands and the wires renewed if necessary. Renewed falls should not be excessive in length, for the winch drum is designed to take only the correct amount of wire.

If any doubt is felt as to the condition of any of the foregoing, or indeed any aspect of a particular set of davits, then the affected part should be stripped down and dealt with as necessary. A full test on an individual davit using the data on the test stamping or from the davit certificates should be the final criterion of acceptability. Alternatively, a full boat lowering test with the boat ballasted to the correct test weight should be carried out. Similarly if major repairs are required, a proof test should be applied on completion.

It is emphasized that no certificate of any type should be issued in respect of a davit or davit system, if any doubt exists as to its effectiveness or efficiency as part of the lifesaving apparatus of the vessel. Finally it cannot be over emphasized that these notes are for guidance only and should not be regarded as presenting an exhaustive scheme designed to locate all possible faults in davits.

When new gravity davits have been set up for the first time it is necessary to verify that the floating blocks will clear the horns in the davit heads with the ship listed 20 degrees either way, the horns usually being initially longer than required to enable fine adjustments to be made on board the ship with the lifeboat in place. If the horns are too long then the blocks might not clear at the required angle and if they are too short this might result in the blocks becoming unshipped at some point when being run out with the ship upright. Various methods can be used for checking the angle at which the blocks will clear the horns.

The following is proposed for this purpose. Verify that the ship is upright and run out the davits to their full outboard position. By the use of a plumb line mark a vertical reference line in a convenient position on each davit arm. Mark a second line on the davit arms to cut this reference line at an angle of 20 degrees and in such a direction that when the davit arms have been moved through an angle of 20 degrees during the course of pulling in the davits, the second line marked will be vertical. Pull in the davits until this second line marked on each davit arm is vertical and chock off the davits in this position by inserting wood chocks between the arms and their outboard stops, or by

other suitable means. Lower the lifeboat a short distance. The blocks should clear the horns with the davit arms in this position thus simulating the ship listed 20 degrees adversely. It is obvious that it is unnecessary to make a similar check for a 20 degrees favourable list.

019 Lifeboat Equipment

All lifeboats on ships built on or after 1 July 1986 are to be equipped with the items as indicated in section 3.7 of the revised Rpt. SE1. On ships built prior to 1 July 1986 the equipment is to be in accordance with the list shown on the previous 1974 version of the Rpt SE1.

By virtue of the fact that 1983 Amendments require all lifeboats to be motor propelled and either fully or partially enclosed and self righting, the following items of equipment are no longer required in new lifeboats:-

gunwale to gunwale grablines
steering oar
mast, stays and sails
exposure cover
oil lamp
two boxes of matches
storm oil and bag

Each new lifeboat is to be provided with the following equipment, the reference numbers relate to the item numbers on the SE1.

3.7.2 Sufficient buoyant oars to make headway in a calm sea.

3.7.3 Thole pins, or crutches are to be available for each oar. Crutches are to be galvanised, of uniform pattern and interchangeable throughout the boat. If thole pins are used one set of pins equates to one crutch. These items are to be attached to the boat by lanyards or chains.

3.7.4 A permanently installed earth connection, together with securing arrangements for the erection and operation of the antenna provided with the portable radio apparatus, is to be sited within the lifeboat.

3.7.5 & 3.7.6 At least one drain valve is to be fitted in the lowest part of the lifeboat so as to allow free drainage of the interior when the boat is not waterborne. The valve is to automatically close to prevent the ingress of water when the lifeboat is waterborne. A cap or plug is to be permanently attached by lanyard or chain to each drain valve. The position of each valve is to be clearly indicated on the inside of the boat.

3.7.7 The rudder is to be permanently attached to the lifeboat. If a steering wheel or alternative steering mechanism is fitted then the tiller may be of the removable type and securely stowed near to the rudder stock. If a remote steering mechanism is not fitted then the tiller is to be permanently installed on, or linked, to the rudder stock.

3.7.8 A buoyant lifeline is to becketed around the outside of the lifeboat, except within the vicinity of its rudder and propeller.

3.7.9 A manually operated bilge pump fitted with a suction and hose for discharging water over the side is to be provided. The pump is to be easily opened for cleaning and examination without the use of special tools.

3.7.10 Sufficient watertight lockers or compartments are to be provided for storage of small items of equipment, water and provisions.

3.7.11 Two painters each of length equal to at least twice the distance from the lifeboat stowage position to be lightest seagoing waterline or 15 metres, whichever is the greater, are to be supplied within the lifeboat. One painter is to be secured at the forward end of the boat to a device which will allow release of the painter whilst under tension. The second painter is to be firmly secured at the bow ready for immediate use.

3.7.12 Two boat hooks are to be available in the boat and should be at least 2.4 metres in length with a minimum mid-shaft diameter of 50mm.

3.7.13 A food ration of not less than 10,000 Kilojoules (kJ) for each person the lifeboat is permitted to carry is to be kept in airtight packaging and stowed in a watertight compartment in the boat.

3.7.14 At least 3 litres of fresh water per person is to be stored in watertight receptacles in the boat. De-salting apparatus may replace 1 litre of the aforementioned 3 litres providing it is capable of producing 1 litre of water within 2 days. Means are also to be provided for the collection and storage of rainwater.

3.7.15 One set of approved distress pyrotechnic signals com-
3.7.16 prising four red parachute flares, six red hand flares and
3.7.17 two buoyant orange smoke signals are to be stowed in a readily available watertight container.

3.7.18 A buoyant baler fitted with a lanyard.

3.7.19 Two buckets are to be stored one forward and one aft. They may be plastic or galvanised and should be of approx. 9 litres capacity. Each bucket it to be fitted with a lanyard.

3.7.20 Two single edge hatchets with lanyard are to be secured in the lifeboat ready for immediate use. One should be located at each end of the boat.

3.7.21 One efficient compass in a binnacle is to be permanently fitted at the steering position of totally enclosed lifeboats. Suitable mounting arrangements for the binnacle are to be provided in partially enclosed lifeboats. The compass is to be luminous or provided with a suitable means of illumination. The compass card should not be less than 100mm diameter.

3.7.22 A sea anchor is to be supplied for use in adverse weather conditions to keep the boat head in to wind and sea. The sea anchor, which is generally a cone shaped canvas bag, should be approximately 1.25 metres in length with an opening at the mouth of about 700mm diameter. A shock resistant hawser about three times the length of the boat should be attached to the mouth and a tripping line, which will provide a firm handgrip when wet, is to be secured to the point. The tripping line should be about 3 metres longer than the hawser.

3.7.23 A rustproof dipper with lanyard or rustproof chain is to be available for use with the fresh water.

3.7.24 A rustproof graduated drinking vessel or beaker is also to be supplied.

3.7.25 An approved first aid outfit with unbroken seals and fitted in a watertight case is to be stowed in the boat.

3.7.26 A waterproof electric torch suitable for signalling by

NOTES

Morse together with a spare set of batteries and bulb is to be supplied in a watertight container.

3.7.27 The daylight signalling mirror is also to be supplied with instructions for use in signalling ships and aircraft.

3.7.28 A jack-knife, which should be greased or otherwise protected against corrosion, is to be permanently attached to the lifeboat by it's lanyard and should generally be located at the coxswain's or helmsman's position.

3.7.29 A whistle, reed-horn or equivalent sound signalling apparatus is to be on board.

3.7.30 One set of fishing tackle which should comprise a line with six hooks and preferably some artificial lures is to be provided.

3.7.31 A table of life-saving signals is to be stowed in a watertight container in the lifeboat, alternatively these signals may be on a waterproof card. The signals depicted on the card are to comply with Regulation 16 of Chapter V of SOLAS.

3.7.32 A boarding ladder, capable of being used on either side of the lifeboat, to enable persons in the water to board the boat. The lowest step of the ladder is not to be less than 400mm below the lifeboat's light waterline.

3.7.33 Skates and fenders are to be fitted as necessary to facilitate launching and prevent damage to the lifeboat, especially when launching against an adverse list.

3.7.34 Handholds are to be fitted on the underside of the hull of lifeboats which are not self righting. The handholds are to be fastened to the hull in such a way as to break free on impact without damaging the lifeboat.

3.7.35 A survival manual is to be supplied giving advice on the use of the boats equipment, distribution of rations and water, protection from the elements and the importance of maintaining morale.

3.7.36 For each person the lifeboat is certified to carry there is

3.7.37 to be six doses of antiseasickness medicine and one seasickness bag.

3.7.38 Three tin openers are to be supplied and should be suitably protected against corrosion.

3.7.39 Two buoyant rescue quoits are to be attached to not less than 30 metres of buoyant line each.

3.7.40 A searchlight which is to be capable of illuminating a light coloured object 18 metres wide at night from a range of 180 metres for a total period of 6 hours, at least 3 of which are to be continuous.

3.7.41 An efficient radar reflector is to be fitted on the lifeboat.

3.7.42 Sufficient thermal protective aids are to be available for ten per cent of the total number of persons the lifeboat is permitted to carry with a minimum of two.

3.7.43 A lamp or light source is to be fitted inside the boat to provide illumination for not less than twelve hours. The intensity is to be sufficient for reading of survival and equipment instructions. Oil lamps are not permitted.
A manually controlled external lamp is also to be fitted on top of the cover or enclosure. It should have a range on a clear night of 2 miles for period of 12 hours. If the lamp is a flashing type, the frequency over the first 2 hours of operation is to be not less than 50 flashes per minute.

3.7.44 Sufficient tools are to be available for minor adjustment to the lifeboat engine and its accessories.

3.7.45 A safety belt is to be fitted at each seating position in all self-righting lifeboats.

3.7.46 Arrangements for securing the survival craft portable radio apparatus are to be fitted.

When verifying survival craft equipment at surveys all equipment should be collected together, to be checked for continued efficiency and compliance with the record of Safety Equipment (Rpt. SE1).

Mast and sails, where provided, should be rigged, in order to ensure continued efficiency.

Exposure covers should be placed in position and securing, and support arrangements carefully examined in order to confirm the arrangements remain efficient.

Skate securing arrangements should be carefully examined, together with their means of release from the lifeboat. The opportunity should also be taken to carefully examine the hull of the lifeboat in way of the skates.

Water and ration tanks should be carefully examined at each survey to ensure that their filling and closing arrangements remain efficient and that the entry of contaminents is prevented.

The Surveyor should ensure that rations, in accordance with the national requirements, are provided and that such rations are replaced as and when required.

Radio equipment will normally be tested at the time of the Radio Survey, but at Safety Equipment Surveys the Surveyor should satisfy himself that the arrangements for securing the portable radio equipment and aerials in the lifeboat remain efficient. [See also radio survey notes].

Pyrotechnic Signals must be renewed if the expiry date shown on the pyrotechnics has passed or if the period of time allowed by the National Administration before renewal is required, has expired. However, in all cases where the condition of the pyrotechnics gives cause for concern they should be replaced.

First Aid outfits should only be opened if from external examination the contents appear to have been damaged. In such cases the outfit should be replaced.

Tinned water stored under good conditions can last for several years. Care should be taken to ensure that the tins have suffered no damage nor show signs of rust or corrosion. Dents in the tin within 13 mm of a seam are not acceptable and the tin should be replaced. Tins can be tested for loss of vacuum by striking the rim of the tin with the palm of the hand. A sharp click will indicate that the vacuum is intact, however, a dull sound indicates a loss of vacuum, in which case the tin should be replaced.

020 Lifeboats for Restricted Trading

Lifeboats are to be of the totally enclosed self-righting type unless the ship is trading in favourable climatic areas where the administration may permit partially enclosed self-righting lifeboats to be used. The limits of trading area when partially enclosed boats are used are to be endorsed on the Cargo Ship Safety Equipment Certificate.

021

All lifeboats built to comply with the 1983 Amendments are to be powered by a compression ignition engine the fuel for which must have a flash point in excess of 43°C (closed cup test). The engine may be manually started, but if power started at least two independent rechargeable energy sources are required. It must be possible to start the engine without removing thwarts, engine casings or other obstructions. The starting mechanisms are to be capable of starting the engine at an ambient temperature of – 15°C within 2 minutes of commencing starting procedures and the engine is to be capable of running for at least 5 minutes, from cold, without the lifeboat being in the water. Water resistant instructions for starting and operating the engine are to be conspicuously placed near the engine starting controls. The engine must also operate when the lifeboat is flooded up to the centreline of the crankshaft.

Provision is to be made to disengage the engine drive from the propeller and for ahead and astern propulsion of the lifeboat. The lifeboat speed in calm water, when fully loaded with persons and equipment, and with all engine powered auxiliary equipment in operation, is to be at least 6 knots and at least 2 knots when towing a fully laden and equipped 25 person liferaft. Sufficient fuel is to be available to sustain this speed in the fully loaded condition for at least 24 hours.

The lifeboat engine, transmission and accessories are to be enclosed in a fire retardant casing which will also protect the engine from exposure to weather and sea and safeguard the occupants of the boat from contact with any hot and/or moving

parts. Starter batteries are also to be housed in enclosures with watertight bottoms and sides and with a suitable top to provide battery gas venting.

Means are to be provided to recharge from the lifeboat engine, batteries for radio, searchlight and engine starting. A similar recharging capability from the ships power supply is also to be arranged. Radio batteries are not to be used for engine starting. The running of the engine must not adversely affect the quality of radio transmission and reception within the lifeboat.

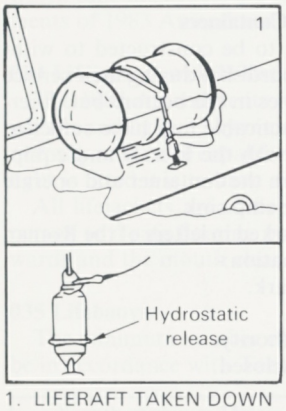
At least one fire extinguisher suitable for extinguishing oil fires is to be located in the vicinity of the engine. It is considered that CO_2 may be the most effective type of fire extinguisher for use in a lifeboat.

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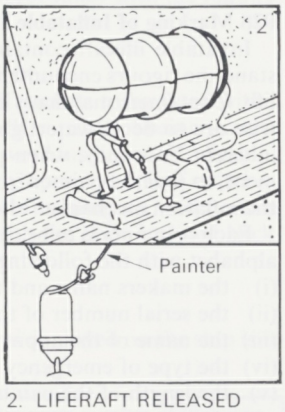
The dimensions of the lifeboat and number of persons it is permitted to carry are to be marked on the boat in clear permanent characters. The name of the ship and port of registry are to be marked in block capitals of the Roman alphabet on each side of the bow. It should also be possible to identify the ship to which the lifeboat belongs from the air. The letters should be large white capitals of the Roman alphabet giving the ship's name and/or signal letters.

023 Rigid Liferaft Equipment

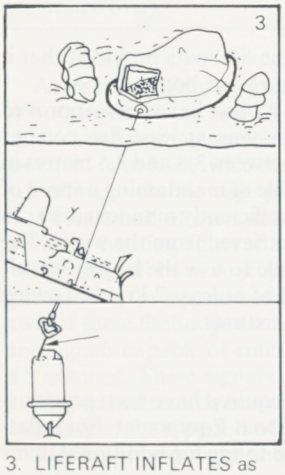
Descriptions of the various items of equipment required in rigid liferafts may be found where applicable in section 019. Lifeboat Equipment.



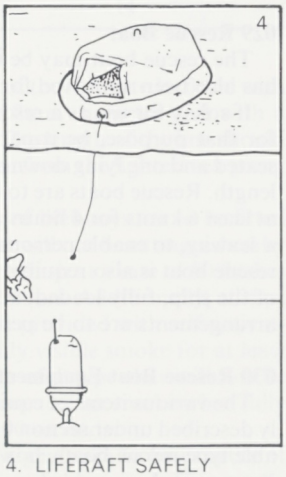
1. LIFERAFT TAKEN DOWN WITH SINKING SHIP



2. LIFERAFT RELEASED UNDER-WATER but painter still connected to ship through weak link



3. LIFERAFT INFLATES as painter becomes taut



4. LIFERAFT SAFELY RELEASED as weak link parts

Fig 8

024 Marking of Rigid Liferafts

Similar markings are required on rigid liferafts as on the containers of inflatable liferafts. In addition however the following should also be marked:-

i) The name and port of registry of the ship to which the liferaft belongs.

ii) At each entrance the number of persons which the liferaft is permitted to accommodate.

025 Liferafts (excluding additional rafts stowed forward or aft)

Figures 1 to 5 illustrate the various requirements for the number and disposition of liferafts. Inflatable liferafts and inflatable boats should only be serviced at approved service stations. Only service stations approved by the manufacturer will be equipped with the relevant service and packing manuals, spare parts, adhesives and material compatible with the original raft or boat.

During the visual examination of inflatable liferafts and boats particular attention should be given to the stowage and quick release arrangements fitted. Additionally, the packing and sealing arrangements of valises or containers should be specially examined. At the time of Renewal, Annual or Intermediate Safety equipment survey, valid service certificates should be verified on the vessel for all inflatable liferafts, boats and lifejackets.

It is not unusual to find that liferafts are lashed in position to prevent their loss overboard during heavy weather. It is not a requirement of the Convention that liferafts be lashed, but if lashed, then an approved automatic release system is to be provided. The requirements of the Convention are better illustrated by the arrangements shown in Figure 8.

At surveys it is important to verify that containers are stowed with the weak link at the inboard end of the painter secured to the ship (the painter itself must not be fastened to the ship) and able to float free and inflate. Lashings where used must be fitted with a hydrostatic or equivalent automatic release mechanism so as to enable the liferaft to float free and inflate.

Temporary ties used to secure the two halves of a container together during transit from a service station to a ship must be removed unless clearly marked with instructions to the contrary. The weather-tight sealing arrangement between the two halves should not be tampered with.

Should "extra" lashings be found which would negate the operation of the automatic float free arrangements they should be removed immediately and the Master's attention drawn to this safety hazard.

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026 Additional Liferafts forward and/or aft

Where the distance from the stem, or stern, to the main survival craft station is more than 100 metres an additional liferaft of at least six persons capacity is to be arranged as far forward and/or aft as possible. These liferafts need not be of davit launchable type nor be fitted with automatic float free arrangements. Any securing arrangements of these liferafts are, however, to be capable of efficient manual release.

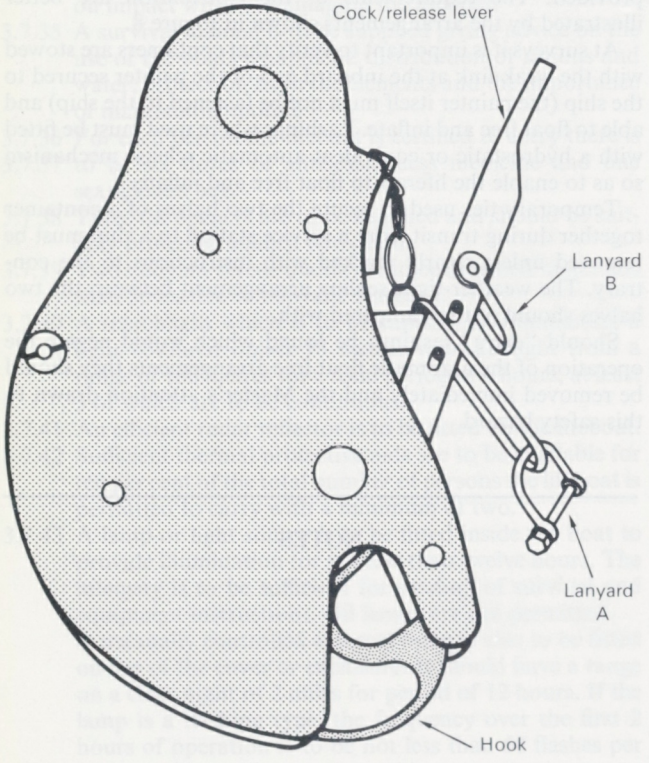
027 Liferaft Launching Appliances

The requirements for liferaft launching appliances are the same as those for lifeboats with the exception that the liferaft davit may be manually turned and/or slewed into the liferaft inflation and embarkation position.

Liferaft launching appliances should comply with paragraphs (a) to (p) inclusive of section 018 New Ship Requirements except with regard to the use of gravity for turning out the appliance, embarkation in the stowed position and recovery of the loaded liferaft.

Liferafts which are lashed or secured in their stowage position are to have their painters secured by the weak links to a convenient part of the ship's structure (see figure 8). A hydrostatic release device is to be incorporated in the securing arrangement so that in the event of the ship sinking before the liferafts have been deployed they will:-

(i) break free from stowage by automatic activation of the hydrostatic release.
(ii) float towards the surface.



1. Pull cocking/release lever DOWNWARDS to open Hook.
2. Engage HOOK on Liferaft lifting shackle, or ring, close Hook by sharply and firmly pushing cocking/release lever fully UP.
3. Hook should be set (to open automatically) by pulling sharply and firmly DOWN on Lanyard A and it is recommended that the Hook be set just before the Liferaft reaches the sea surface.
4. In the event of the Hook not opening and releasing the Liferaft when in the water, it is possible by pulling firmly on Lanyard B to open the Hook.

Fig 9 Davit Liferaft Automatic Release Hook

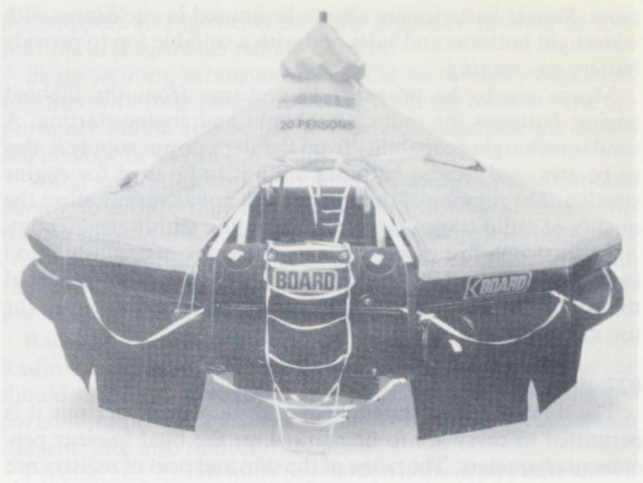


Fig 10 Typical Inflatable Liferaft

(iii) inflate by virtue of the pull of the sinking ship on the inflation painters.
(iv) free themselves as the ship continues to sink through breakage of the weak links.

Release hook arrangements are to be such as to prevent premature release during lowering but ensure release of the liferaft when waterborne. A typical device is shown in Figure 9.

028 Marking of Inflatable Liferaft Containers

Inflatable liferaft containers are to be constructed to withstand the rigours encountered onboard ship during their service life. Containers may have drain holes in the bottom but otherwise are to be as watertight as practicable and have sufficient inherent buoyancy, when packed with the liferaft and equipment, to pull the painter from within the container and operate the inflation mechanism should the ship sink.

Each container is to be clearly marked in letters of the Roman alphabet with the following information:-

(i) the makers name and trade mark.
(ii) the serial number of the raft.
(iii) the name of the approving authority.
(iv) the type of emergency pack enclosed.
(v) the length of the painter.
(vi) the maximum permitted stowage height above the waterline.
(vii) launching instructions.
(viii)the date of the last service.

029 Rescue Boat

The rescue boat may be one of the lifeboats provided that it has also been approved for use as a rescue boat.

If solely for use as a rescue boat it must have been approved for that purpose, be capable of carrying at least five persons seated and one lying down and be between 3.8 and 8.5 metres in length. Rescue boats are to be capable of maintaining a speed of at least 6 knots for 4 hours and be sufficiently manoeuvrable, in a seaway, to enable persons to be retrieved from the water. The rescue boat is also required to be able to tow the largest liferaft of the ship, fully loaded, at a speed of at least 2 knots. Towing arrangements are to be permanent fixtures.

030 Rescue Boat Equipment

The various items of equipment required have been previously described under section 0.19. Lifeboat Equipment. For inflatable type rescue boats, however, the following additional items are required:-

(i) a buoyant safety knife.
(ii) two sponges.
(iii) an efficiently operated bellows or pump.

(iv) a repair kit in suitable container for repairing punctures.
(v) a safety boat-hook, usually of conventional form with a ball affixed to each point or of the 'shepherds crook' type.

031 Launching and Recovering Arrangements for Rescue Boats.

The requirements for launching and recovering of rescue boats are the same as those for lifeboats but with the additional requirement that any recovery arrangements be of sufficient capacity as to be able to recover the rescue boat, with a full complement of persons and equipment, at a minimum rate of 0.3 metres/second.

Rescue boat launching and recovery appliances should comply with paragraphs (a), (b), (c), (d), (e), (f), (g), (h), [(i) if applicable] (j), (k), (l), (m), (n), (o) and (p) of section 018 New Ship Requirements. In addition they are to be capable of recovering the boat with its full complement of equipment and persons it is certified to carry as a rescue boat from the water by use of a powered winch at a rate of not less than 0.3m/sec.

032 Rescue boat engine

Propulsion of boats that are solely rescue boats, may be by inboard or outboard engines. If fitted with an outboard engine the rudder and tiller may form part of the engine. Petrol driven outboard engines with an approved fuel system may be fitted in these boats provided the fuel tanks are specially protected against fire and explosion.

033 Lifejackets with whistle attached

This section is applicable to pre 1983 Amendment ships where lifejackets of this type will be acceptable until 1 July 1991 after which time lifejackets are to be in accordance with the requirements of 1983 Amendments.

034 Lifejackets with Whistle and Light

The 1983 Amendments require lifejackets to be fitted with a whistle and light. They must be clearly capable of being worn in one way only or be capable of being worn inside out. If a flashing light is fitted it is to have a manually operated on/off switch.

All lifejackets are to be capable of turning an unconscious person to a safe floating position with the body inclined backwards and the mouth clear of the water.

035 Lifebuoys

The minimum number of lifebuoys deployed on the ship is to be in accordance with Table 3.

Length of ship in Metres	Minimum number of lifebuoys
Under 100	8
100 and under 150	10
150 and under 200	12
200 and over	14

Table 3

At least one lifebuoy on each side of the ship is to be fitted with a buoyant heaving line of at least 8mm diameter and with a minimum breaking strain of 5 kN. The length of the line should be equal to at least twice the distance from the lightest sea going waterline to the stowage position.

At least half of the total number of lifebuoys are to be fitted with self-igniting lights of a type that will not be extinguished by water and will burn continuously, or flash at a rate of 50 flashes per minute, for a period of at least 2 hours. Additionally, at least two of these lifebuoys are also to be provided with self-activating signals capable of emitting highly visible smoke for at least 15 minutes. These signals are to be of a type that will not be swamped in a seaway but will continue to emit smoke when fully submerged for a period of at least 10 seconds.

Lifebuoys with light and smoke signals are to be capable of quick release from the navigating bridge and be equally distributed on each side of the ship. Lifebuoys fitted with lights only are also to be equally distributed on each side of the ship.



Fig 11 Immersion Suit

NOTES

Lifebuoys fitted with lights or light and smoke signals must not be the same lifebuoys required to be provided with lifelines. Each lifebuoy is to be marked in block capital letters of the Roman alphabet with the name and port of registry of the ship to which it belongs. A grabline is to be fitted around the outside diameter of all lifebuoys and secured at equidistance points so as to form four equal loops.

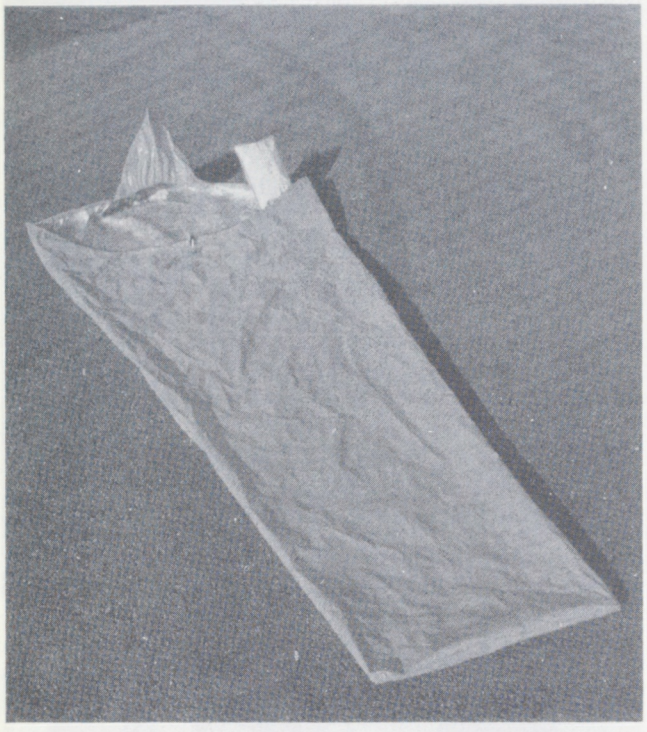


Fig 12 Thermal Protective Aid

036 Immersion Suits (Fig 11) and Thermal Protective Aids (Fig 12)

All ships constructed on or after 1 July 1986 are to be provided with approved immersion suits for:-

(a) at least three persons for each lifeboat on the ship;
(b) each person assigned to crew the rescue boat (care should be taken to ensure that, if one of the lifeboats is designated a rescue boat, the correct number of suits are provided if the required crew as a rescue boat exceeds three in number)

And for those persons on-board the vessel not provided with an approved immersion suit an approved thermal protective aid. However, if the Flag Administration considers it necessary then an approved immersion suit is to be provided for each person on board the ship.

Immersion suits and thermal protective aids are not required to be provided on those cargo ships which are:-

(a) equipped with totally enclosed lifeboats on each side of the ship of aggregate capacity to accommodate the total number of persons on board; or,
(b) equipped with totally enclosed lifeboats capable of being launched by free-fall over the stern of the ship of such aggregate capacity as will accommodate the total number of persons on board and which are boarded and launched directly from the stowed position, together with liferafts on each side of the ship of aggregate capacity to accommodate all the persons on the vessel; or,
(c) is constantly engaged on voyages in warm climates where, in the opinion of the Administration, immersion suits and thermal protective aids are unnecessary.

Cargo ships of less than 85 metres registered length fitted with arrangements which incorporate liferafts in lieu of lifeboats (an arrangement permitted on cargo ships other than oil tankers, chemical tankers and gas carriers) are required to carry an immersion suit for every person on board unless the ship:

(a) has davit launched liferafts; or,
(b) has liferafts served by equivalent approved appliances capable of being used on both sides of the ship and which do not require entry into the water to board the liferaft; or,
(c) is constantly engaged in warm climates where in the opinion of the Administration immersion suits are unnecessary.

Immersion suits are to be of waterproof material, designed and packed in such a way as to be donned unaided within 2 minutes. This includes a lifejacket if it is not an integral part of the suit. It is to cover the whole body with the exception of the face. Hands are to be covered unless permanently attached gloves are fitted.

Thermal protective aids are also to be made of waterproof material. Each aid should be large enough to cover the whole body except the face, or hands if permanently attached gloves are fitted. The aid is to be easily unpacked and donned without assistance and is to be capable of removal within 2 minutes in water if it impairs swimming ability.

037 Retro-reflective Tape

All survival craft, lifebuoys and lifejackets are to be fitted with retro-reflective material. Figure 13, illustrates typical examples.

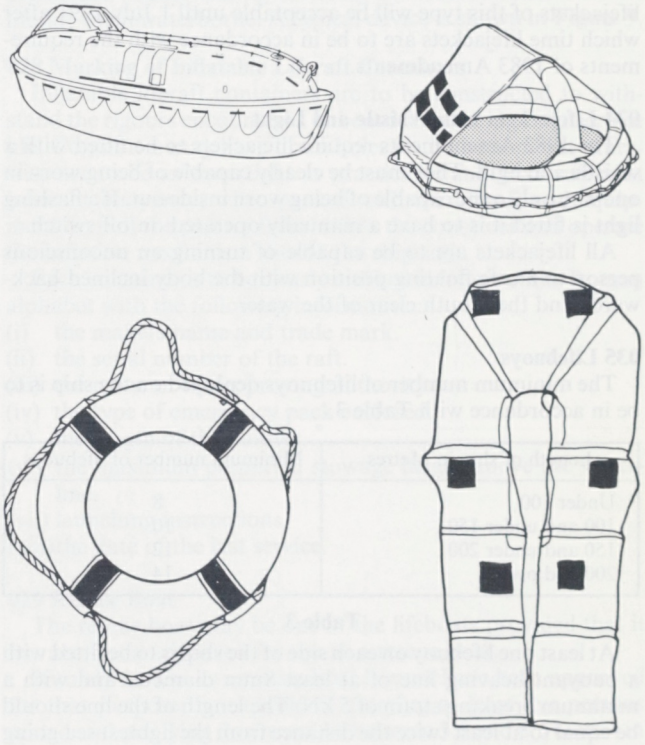


Fig 13 Typical Retro-reflective Marking

For lifeboats tapes should be fitted on the top of the gunwale as well as on the outside of the boat as near the gunwale as possible. The tapes should be sufficiently wide and long (approximately 5 × 30cm) and should be spaced at suitable intervals (approximately 50cm). If a canopy is fitted it should not be allowed to obscure the tapes fitted on the outside of the boat and the top of the canopy should be fitted with retro-reflective tapes similar to those mentioned above but shaped in the form of a cross and spaced at suitable intervals (approximately 50cm).

For liferafts tapes should be fitted around the canopy of the raft at suitable intervals (approximately 50cm) and at a suitable height above the waterline. On inflatable liferafts retro-reflective tapes should also be fitted on the underside of the floor (four tapes fitted at equal intervals around the outer edges on the bottom of the liferafts). The tapes should be sufficiently wide and long (approximately 5 × 30cm). A suitable cross shaped marking of two such tapes should also be applied to the top of the canopy. On rafts which are not equipped with canopies at least four such tapes should be attached to and evenly spaced on the buoyancy chamber in such a manner that they are visible both from air and sea.

For lifebuoys tape of a sufficient width (approximately 5cm) should be applied around or on both sides of the body of the buoy at four evenly spaced points.

Lifejackets, unless the cover material is retro-reflective, should be fitted with retro-reflective tapes sufficiently wide and long (approximately 5 × 10cm). These tapes should be placed as high up on the jacket as possible in at least six places on the outside and in at least as many places on the inside by virtue of the fact that lifejackets are reversible.

038

Not less than two designated fire pumps are to be located in the main machinery space and in addition one of the general service pumps, bilge and ballast pumps, or other similar pump is to be connected to the fire main. However, this connection is required only if one of these pumps already has the required capacity and discharge pressure. The total capacity of fire pumps should be two thirds of the quantity required for bilge pumping but need not exceed 180 m^3/hour. Sanitary, bilge, ballast and general service pumps can be used for fire fighting purpose, providing they are not normally used for pumping oil. Occasional duty for pumping or transfer of oil with suitable changeover arrangements is permissible.

In tankers, fire pumps are not to be situated in pump rooms, cofferdams and other spaces liable to contain explosive vapours or in spaces immediately adjacent to cargo oil or slop tanks. It should be ensured that door and ventilator openings to the compartment and any air inlets for the pump are situated, in relation to cargo tank openings such as vent pipes and P.V. valves, to preclude the possibility of drawing dangerous vapours into the compartment.

039 Emergency Fire Pump

In cargo ships of 1,000 G.T. and upwards, if a fire in any one compartment would put all the fire pumps out of action, there must be an alternative means of providing water for fire fighting consisting of a fixed independently driven emergency fire pump capable of supplying two satisfactory jets of water with a throw of not less than 12 metres.

The capacity of the pump is to be not less than 40% of the total required capacity of the main fire pumps but not less than 25 m^3/hour.

Whether electrically or diesel powered, the emergency fire pump should be situated so that it will not be readily affected by smoke or fire from the space containing the main fire pumps. If diesel driven, the power source is to be readily started by hand in ambient temperatures of down to 0°C. If necessary, heating arrangements should be installed.

Where batteries are the sole means of starting, two sets should be provided each set being capable of six starts within 30 minutes and at least twice within the first 10 minutes. One of the sets of batteries should be on constant trickle charge and a hand started battery charger is to be provided. The service fuel tank for diesel driven pumps would normally be in the same compartment and must contain sufficient fuel to run the pump for three hours on full load. A reserve tank holding sufficient fuel for a further 15 hours at full load is also to be provided. Air inlets to the space containing the pump should be arranged to minimise the possibility of engine failure due to ingress of smoke or water. If electrically driven, the source of power should be the emergency generator and electric cables from the generator to the emergency fire pump should not pass through the space containing the main fire pumps. The emergency fire pump should preferably have an independent sea suction located outside the space containing the main fire pumps. Where the pump is located such that the sea suction requires to be fitted inside the engine room then the sea inlet valve should be controlled from a position adjacent to the emergency fire pump. The valve should remain in the open position at all times and be controlled by an extended spindle or hydraulic operation such that in the event of power failure the valve stays open.

Any suction pipe located inside the engine room is to be encased in a substantial steel trunk or alternatively be of heavy gauge pipe. The sea suction should be located such that efficient operation will be maintained in all conditions of list and trim likely to be encountered.

The 1948 Convention required ships of 1000 G.T. and upwards, if fitted with oil fired boilers or internal combustion machinery, to be provided with an "alternative means" of fire extinguishing in the event of a fire in any one compartment rendering all the fire pumps inoperable. The absence of the word "water" which appears in all subsequent Conventions led to the acceptance of a smothering gas installation as an "alternative means". With such an existinguishing system, if a fire occurred in the compartment containing the fire pumps or their source of power, the space could be evacuated and the fire dealt with by releasing the smothering gas from outside the space.

040 Isolating Valves and Fire Main (See Appendix A)

Isolating valves are to be fitted to segregate the rising main within the space containing the main fire pump or pumps from the rest of the fire main. These valves must be fitted outside the space in an easily accessible and tenable position. The fire main should be arranged so that when the machinery space isolating valves are shut all other hydrants in the ship can be supplied with water from pipes which do not re-enter the machinery space.

The fire main should be available for fire fighting purposes at all times and permanent connections to other services are not generally permitted. It is, however, permissible to fit branches for such low demand services as hawsepipe cleaning and forepeak and chain locker bilge eductors. The topside water ballast tanks in vessels carrying low fire risk cargoes may be filled through a flexible hose connected to the fire main. This hose should be immediately removed after use and a notice to this effect prominently displayed at each connection point.

NOTES

041 Hydrants

The arrangement of hydrants is to be such that two jets of water, not from the same hydrant, may reach any part of the ship normally accessible to passengers or crew and any part of the cargo spaces when empty. One of these jets should be from a single length of hose. In special category spaces the two jets are both to be from single lengths of hose.

042 Hoses and Nozzles

In cargo ships over 1000 G.T. there is to be at least one hose for each 30 metres length of the ship plus one spare, but in no case less than five in all. This number does not include hoses required in engine or boiler rooms. In cargo ships less than 1000 G.T. not less than three hoses are required.

Fire hoses are to be of approved materials and are generally made of P.V.C. coated synthetic textiles. Most hoses are also rubber lined. Hoses are to be of sufficient length to project a jet of water into the spaces they are to protect, the usual length being about 18 metres but should not exceed 20 metres. For external locations, whilst a 65mm hose is acceptable, a more realistic figure for ease of handling is 50mm and for internal locations 38mm is considered adequate.

Nozzles should be 12mm or 16mm and need not exceed 19mm and be dual purpose type incorporating a shut off. Nozzles may be manufactured from brass, aluminium and copper alloy, or suitable plastic.

043 Sand Boxes and Scoops

Ships of 1000 G.T. and over with oil-fired main or auxiliary boilers should be provided, in each firing space, with a receptacle containing sand, sawdust impregnated with soda, or other approved dry material suitable for quenching oil fires, together with a scoop for distributing this material. The quantity supplied is dependent on the flag administration requirements but generally about $0.3m^3$ will suffice. Alternatively, a portable fire extinguisher suitable for extinguishing oil fires may be provided in lieu and this is generally the case on new buildings today.

044 International Shore Connection

An international shore connection should be provided with facilities for its use on either side of the ship to enable the deck main to be supplied with water from ashore.

045 Fire Extinguishers (See Appendix B)

Engine rooms containing internal combustion propulsion machinery and any other spaces containing internal combustion machinery of 375 kW or above, ie a machinery space of category 'A', are to be provided with the following fire extinguishers:-

(i) Portable foam extinguishers, or equivalent, so located that no point within the space is more than 10 metres walk from an extinguisher. A minimum of two are required.

(ii) Foam extinguishers of at least 45 litres capacity, or equivalent, sufficient in number to enable foam to be directed onto any pressurized fuel or lubricating oil system or similar hazard.

In spaces containing oil fired boilers or oil fuel units used for the preparation and/or delivery of oil including pumps, filter and heaters with a working pressure in excess of $0.18\ N/mm^2$, also known as machinery spaces of category 'A', the following fire extinguishers are to be provided:-

(i) Two portable fire extinguishers in each firing space and in each area where an oil fuel installation is located.

(ii) At least one foam extinguisher of 135 litres capacity fitted with a hose on a reel so as to ensure the delivery of foam to any part of a boiler room. This requirement may be relaxed in cargo ships with respect to domestic boiler installations of less than 175 kW.

Steam turbine rooms or spaces containing enclosed steam engines with an aggregate power output of 375 kW or above are to be provided with the following:-

(i) Sufficient portable foam extinguishers so located that no point in the space is more than 10 metres walking distance from an extinguisher. A minimum of two are required.

(ii) Foam extinguishers of 45 litres capacity sufficient in number to enable foam to be directed onto any pressure lubricating system or similar hazard.

An extinguisher is also to be provided for dealing with fires at switchboards and other electrical appliances. Extinguishers discharging foam are unsuitable for this purpose and those containing a non-conducting medium such as carbon dioxide, or dry chemical are to be used.

Pump rooms in tankers are to be provided with two portable foam extinguishers or equivalent, one at the pumps and one at the pump room entrance. Cargo pump rooms and compressor rooms of liquefied gas carriers are to be provided with two portable dry chemical extinguishers or equivalent in each space.

In Ro-Ro cargo spaces at least one portable fire extinguisher is to be provided close to each exit.

A spare charge is to be provided for every required portable fire extinguisher, except those that cannot be readily recharged while the ship is at sea (such as carbon dioxide) and an additional portable fire extinguisher of the same type is to be provided in these cases. Duplicate extinguishers may satisfy the requirements for spare charges.

046 Portable Foam Applicator

At least one set of portable foam equipment is required in internal combustion machinery spaces of category A. Ro-Ro cargo spaces intended for the carriage of vehicles with fuel in their tanks are also to be provided with at least one set of this equipment provided that there are at least two sets onboard and available for use in the Ro-Ro space.

The unit should consist of an air foam nozzle of an inductor type and be capable of connection to the fire main by a fire hose. The pressure drop through an inductor is only about 25% thus permitting long runs of hose between the inductor and the foam making branch pipe. A portable container able to hold at least 20 litres of foam making liquid and also one spare tank should be provided. The nozzle is to be capable of producing foam at the rate of at least $1.5m^3$/minute.

047 Fireman's Outfits (See also Appendix C)

All ships are to carry at least two firemans outfits. On tankers two additional firemans outfits are to be provided. The outfits are to be stored so as to be easily accessible and ready for use. Where more than two outfits are onboard they are to be stowed in pairs in widely separated positions.

A firemans outfit consists of the following personal equipment and a breathing apparatus:-

(i) water-resistant clothing of a material suitable for protecting the skin from heat radiating from a fire, from burns and from scalding by steam.

(ii) boots and gloves of rubber or other electronically non-conducting material.

(iii) a rigid helmet providing effective protection against impact.

(iv) an intrinsically safe electric hand lamp capable of operation for at least 3 hours.

(v) an axe with insulated handle.

All breathing apparatus are to be of approved type and may be self-contained, or a smoke helmet or mask type supplied with air from an air pump and a length of flexible hose of sufficient length to reach from the open deck any part of the holds or machinery spaces.

If, in order to achieve this, the length of the hose would exceed 36 metres, a self-contained breathing apparatus must be substituted or provided in addition. The self-contained breathing apparatus provides total flexibility to the wearer, whereas, the air hose is subject to damage, restricts the wearers mobility and is dependent on a second person supplying the air to the user.

The self-contained breathing apparatus has various designs



Fig 14

of equipment but the basic principle is the same for all types. The apparatus should consist of a face mask attached by a flexible hose to one or two cylinders containing air and supported on a frame and harness. The capacity of the apparatus is to be not less than 1200 litres of free air to give nominal functioning time of 30 minutes, however, this depends to a large extent on the breathing rate of the user. Spare air charges of at least 2400 litres of free air are to be provided for each apparatus in addition to the 1200 litres of ready use free air.

All breathing apparatus are to be supplied with a fire proof lifeline of sufficient length and strength which is attached by a snaphook to the harness of the breathing apparatus. Typical fireman's suits are shown in figures 14 and 15.

048 Fixed Fire Extinguishing and Protection Systems

Machinery spaces of category A containing oil fired boilers, oil fuel units or internal combustion machinery are to be fitted with a fixed fire extinguishing system of either CO_2, Halon 1301 or 1211, high expansion foam or pressure water spray.

Cargo spaces of ships of 2000 G.T. and upwards, with the exception of Ro-Ro spaces and other spaces intended for the carriage of vehicles with fuel in their tanks for their own propulsion, are to be protected by a fixed gas extinguishing installation. Exemption from this requirement may be given provided:-

(i) The ship is constructed and intended solely for the carriage of ore, coal, grain, unseasoned timber, non-combustible cargoes and cargoes which are considered to constitute a low fire risk, and

(ii) Hatch covers are of steel and an effective means is provided for closing all ventilators and openings leading to the cargo spaces, and

(iii) Ventilator fans can be stopped and doorways, ventilators and all other openings to cargo spaces can be closed from outside the space concerned.

If ships are exempted from this requirement a notation "no

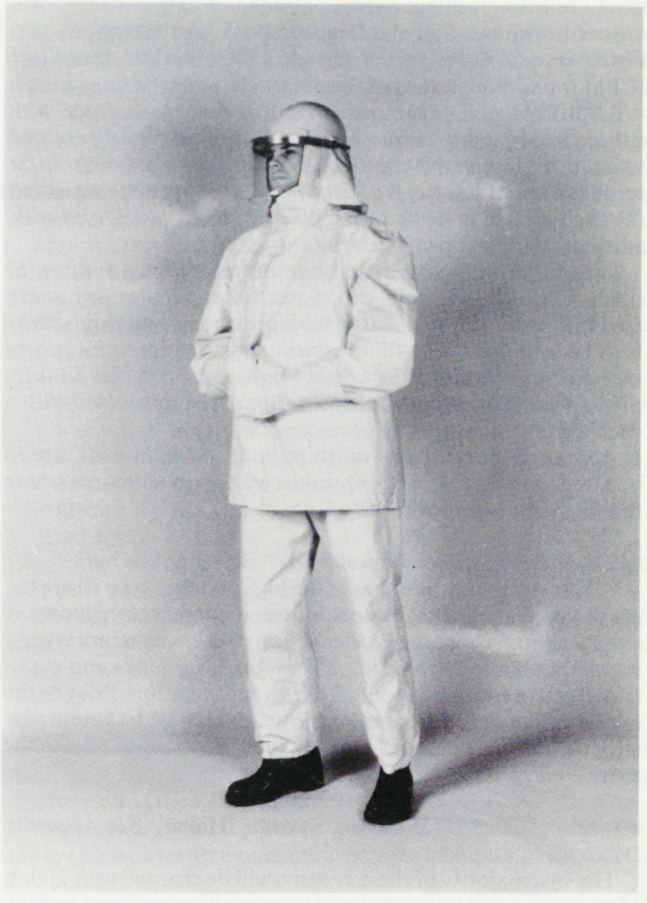


Fig 15

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fixed fire extinguishing system provided in cargo spaces" will appear in column 6 of the Register Book. An exemption certificate is to be issued by the flag administration concerned (see ICPM for authorisations of the Society to issue the Certificate).

Ro-Ro spaces if capable of being sealed are to be fitted with either a fixed gas, high expansion foam, or, if adequately drained so as to overcome the effects of free surface, a pressure water spray system. If the Ro-Ro space is not capable of being sealed the fixed system must be of the pressure water spray type with adequate drainage provided.

Tanker pump rooms are to be protected by fixed systems of either CO_2, Halon, high expansion foam or pressure water spray. The protection of cargo tank deck areas and cargo tanks is to be by a fixed deck foam system and fixed inert gas system on tankers of 20,000 tonnes deadweight and upwards. Tankers of less than 20,000 tonnes deadweight are to be provided with a deck foam system.

Accommodation spaces on ships built to Method IIC are to be fitted with an automatic sprinkler system in all spaces where fire might be expected to originate.

049 CO_2 Systems (See Appendix D)

CO_2 systems may be either of the high pressure type where the gas is stored at ambient temperature in a number of cylinders at a pressure in the region of 48 to 55 bar, or a low pressure type in which the charge is stored in one or more large tanks and maintained at a pressure of about 20 bar by refrigeration. Prior to the release of the gas a distinct audible warning must be automatically sounded in the space into which it is intended to release the gas.

050 Halogenated Hydrocarbon Systems (Halon) (See Appendix D)

The vast majority of these systems will be charged with Halon 1301. The use of Halon 1211 will be specially considered by HQ. Any proposed use of Halon 2402 should be reported immediately to HQ for advice.

Fixed halon systems may be of the high or low pressure type. The high pressure system is very similar to that of a high pressure CO_2 system. The bulk low pressure system will also incorporate a number of high pressure cylinders charged with a gas, usually nitrogen, which is released into the bulk storage tank thus forcing the Halon into the protected space.

Audible alarms, which automatically operate in the protected space prior to the release of any gas, are to be provided.

Systems using Halon 1301 only may have the gas charge stored in individual containers distributed throughout the machinery space. Each container is to be fitted with an over pressure safety release mechanism. A manually initiated power release, located outside the protected space is required for which duplicate sources of power are to be provided, at least one of which is outside the machinery space. Such a system may also be installed in cargo spaces designated only for vehicles which are not carrying cargo.

Local automatically operated systems containing Halon 1301 or 1211 may be fitted in enclosed areas of high fire risk within machinery spaces in addition to, and independent of, any required fixed fire extinguishing system. Notices are to be secured outside the access to these spaces indicating that a local automatic system is installed and stating the gas used. The operation of any local system must be signalled both visually and audibly and escape routes be so arranged to facilitate total evacuation of the space within 10 seconds.

Automatically operated Halon units may be fitted in machinery spaces over equipment having a high fire risk.

051 Fixed Foam Systems (See Appendix E)

Foam systems may generally be divided into two types; the high expansion system used for the protection of engine rooms and the low expansion system installed in way of the cargo tank deck area of tankers.

(a) High Expansion Foam System

High expansion foam is to be generated by units capable of rapidly discharging through fixed discharge outlets a quantity sufficient to fill the greatest space to be protected at a rate of at least 1 metre in depth per minute, with a maximum filling time of 10 minutes.

If the gross horizontal area of the protected space exceeds $400m^2$ at least two foam generators are to be provided. Sufficient foam concentrate is to be provided to produce foam for five fillings of the largest space protected. The expansion ratio of the foam should not exceed 1000 to 1.

Ducts should be made of steel or other suitable material and arranged to deliver the foam quickly to high risk areas. The ducts should include means, such as an automatic flap, so that a fire in the protected space will not affect the foam generating equipment.

The foam generator, its source of power supply, foam concentrate and means of controlling the system should be readily accessible, simple to operate and grouped in as few locations as possible at positions not likely to be cut off by a fire in the protected space.

The water supply is to be from a source outside the protected space and could be from the emergency fire pump provided the capacity is sufficient to satisfy the requirements for the foam system and in addition the demand for two hydrants ($25m^3$/hr) at the required pressure.

High expansion foam will not flow against pressures much above atmospheric pressure and arrangements are to be provided for venting the protected space whilst it is being filled with foam.

(b) Low Expansion Foam System

The risk of deck spillage during loading and discharging and the rupture of the tanks by collision or explosion requires the entire cargo tanks deck area to be protected by a fixed low expansion foam system. Foam should be delivered to monitors and hand applicators by one of two methods:-

(i) The foam solution (i.e. foam concentrate with water added) is to be formed in a main foam control room located aft of the cargo tank area adjacent to the accommodation spaces in a position not likely to be made untenable by a fire in the spaces or areas protected by the system. This room is to contain the supply of foam concentrate, controls and anciliary equipment.

(ii) The foam concentrate is stored in the main foam control room located as (i) and delivered to the monitors and hydrants through a small diameter pipeline where it mixes with water supplied from the fire main, air is induced, expansion takes place and aerated foam is projected.

The deck foam system and the ships main system are to be capable of simultaneous operation in order that the personnel operating the foam fire fighting equipment may be cooled by water spray supplied from the fire main through a hose and nozzle. The main fire pumps should therefore have a sufficient capacity to satisfy the requirements of the foam system and simultaneously provide two jets of water from the fire hydrants.

Sufficient foam concentrate should be supplied to ensure at least 20 minutes of foam generation in tankers fitted with inert gas systems and 30 minutes in tankers not fitted with inert gas systems. The foam expansion ratio should not exceed 12 to 1.

The number of monitors provided and their positions is to be such as to ensure that foam can be delivered to any part of the cargo tanks deck area.

Applicators are to be provided to ensure flexibility of action and to cover areas screened by the monitors. Not less than four applicators are to be provided. Sufficient foam hydrants are to be provided to ensure that foam from at

least two applicators can be directed to any part of the cargo tank deck area. Applicators may replace monitors in ships less than 4000 tonnes deadweight. The capacity of each applicator should be at least 25 per cent of the foam solution rate required by the monitors.

A monitor and hydrant is to be fitted both port and starboard at the poop front of accommodation spaces facing the cargo tank area.

052 Fixed Pressure Water Spray Systems

The systems normally envisaged under this heading are those for the protection of the machinery spaces cargo, pump rooms and Ro-Ro spaces. Whilst accommodation automatic sprinkler systems could be classified as pressure water spray systems they are of course also fire detection systems.

Machinery space systems, sometimes known as Mulsi-spray systems, consist of a water main and branch pipes fitted with nozzles. The nozzles are of a type suitable for extinguishing burning oils and are located to ensure a uniform distribution of water.

The system may be divided into sections with distribution valves operated from a readily accessible position outside the protected space which will not be readily cut off by fire. Water is delivered by a pump capable of supplying, at the required pressure, the necessary demand for the protected space.

The system should be permanently pressurized with the pump starting automatically upon a pressure drop in the system due to the opening of one of the distribution valves. The pump, its controls and sea inlet should be located outside all spaces being protected.

The pressure water spray systems for Ro-Ro spaces, also known as drencher systems have a system of pipes and nozzles evenly distributed on the underside of the deckhead and any hoistable car decks to ensure that all horizontal and vertical surfaces are effectively covered. The system should normally cover the full breadth of the vehicle deck and may be divided into sections provided that they are at least 20 metres in length. The distribution valves for the system are to be situated in a readily accessible position adjacent to, but outside, the protected space and should not be readily cut off by a fire within the space. The space containing the distribution valves is to be adequately ventilated and have direct access provided from the vehicle deck space and from outside that space.

The supply to the system is to be from a water main connected to a sea-water pump where the pump or pumps should be:

(i) Additional to the pumps provided for normal fire fighting purposes. The pumps should be connected to the fire main by a lockable non-return valve to prevent back flow to the fire main.

(ii) Capable of being brought into operation by remote control from the position at which the distribution valves are situated.

(iii) Situated in a position reasonably remote from the protected space.

Systems similar to either of the aforementioned may also be fitted in pump rooms.

053 Automatic Sprinkler, Fire Detection and Fire Alarm Systems (See Appendix F)

This type of system is fitted in accommodation spaces, galleys and service spaces of cargo ships built to Method IIC and as an alternative to an electrical fixed fire detection and fire alarm system in passenger ships.

The system is to be capable of immediate and automatic operation at all times and, except for short sections of pipes, should be of a wet pipe type continuously charged with fresh water at the necessary pressure. Means for giving visual and audible alarms at indicating units should be provided for all sections of sprinklers. Each unit should indicate the location of a fire within a particular section by visual and audible means on the Navigating Bridge and at an alternative manned position.

Sprinkler heads should normally be the frangible bulb type.

Sprinklers are to be placed in an overhead position and spaced so as to maintain an average application rate of not less than 5 litres/m^2 per minute of deck area.

A pressure water tank with a minimum capacity for 2800 litres of fresh water is to be provided in a position remote from category A machinery spaces and not situated in any sprinkler protected space. The arrangement should provide for maintaining an air pressure in the tank.

Means to replenish the air and water, indicate the water level in the tank and prevent the passage of sea-water into the tank are to be provided.

The sprinklers are to be fed from a main connected to a sea-water pump where the pump is:

(i) An independent power pump capable of continuously supplying water to the sprinklers and starting automatically by a pressure drop in the system before the tank of fresh water is exhausted.

(ii) Situated in a position reasonably remote from category 'A' machinery spaces and not situated in any sprinkler protected space.

(iii) Fitted with a test valve with a short open-ended discharge pipe on the delivery side.

The sprinkler system should have a cross connection to the ship's fire main through a lockable screw down non-return valve.

054 Inert Gas System (See Appendix G)

Inert Gas plant is to be capable of supplying 1.25 times the combined volumetric capacity of the cargo oil pumps when discharging at their maximum rate. The gas is to be continuously available and, having been cooled and cleaned, delivered to the cargo tanks with a maximum oxygen content not exceeding five percent.

The inert gas may either be obtained from flue gases or independent inert gas generators.

Independent generators are to be sited clear of the cargo tank area.

055 Dry Powder Systems

These systems are sometimes installed on ships carrying liquefied gases or chemicals in bulk. The powder is stored in a reservoir and is propelled through the delivery lines by a charge of nitrogen which is released under pressure, into the reservoir by operation of the release mechanism at the local control station.

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056 Galley Exhaust Protective System

Exhaust ducts from galley ranges, where passing through accommodation spaces or spaces containing combustible materials, should be fitted with a fire damper, arrangements operable from within the galley for shutting off the exhaust fans, and a fixed means for extinguishing fires within the duct. This fixed means may utilise any of the aforementioned mediums although CO_2 is probably the most common.

057 Fire Protection, Fire Detection and Alarm System

On ships built to Methods IC, IIC or IIIC a fixed fire detection and fire alarm system is to be installed in all stairways, corridors and escape routes within accommodation spaces.

On ships of Methods IIC this installation will be supported in the remaining accommodation and service areas by an automatic sprinkler fire detection and fire alarm system.

Methods IIIC ships are to be protected by a fixed fire detection system in the remaining accommodation and services spaces.

The fire protection arrangements under all the above mentioned methods of construction are to be supplemented by a system of manual call points.

058 General Alarm

The general alarm is to be audible throughout the ship. Electrically operated bells or klaxons are normally used and are to be powered both from the ships main and emergency source of power. The alarms are to be capable of operation from the navigating bridge and other strategic points, with exception of the ships whistle, which is part of the general alarm system and should only be operable from the bridge.

059 Emergency Control/Special Arrangements in Machinery and Accommodation Spaces.

Power ventilation of accommodation, service and cargo spaces, control space and machinery rooms is to be capable of being stopped from an easily accessible position outside the space being served and which will not be readily cut off by fire.

The means for stopping power ventilation of machinery spaces is to be entirely separate to that for accommodation spaces.

Ventilation stops will invariably be located on the engine room switchboard and generally push button stops will be positioned within the engineers accommodation alleyway and/or navigating bridge. Stops for oil fuel pumps may also be similarly positioned. Remote shut downs for oil valves are operated by various systems e.g. pull wires, hydraulic trips etc.

060 Emergency Electrical Power

The emergency source of power will normally be a diesel driven generator which will auto-start on failure of the main power supply. The power from the emergency source must automatically, via the emergency switchboard, supply the required emergency services. If the emergency source is unable to fulfil this function within 45 seconds then a transitional supply from accumulator batteries is required during the interim period up to a maximum of 30 minutes.

061 Location of Emergency Switchboard

The emergency switchboard is to be installed as near as possible to the emergency source of power and if this is a generator it should be in the same space. It must not be located in any space containing accumulator batteries.

II.2 GUIDANCE ON COMPLETION OF PASSENGER SHIP SE1

In order to avoid repetition concerning those items common to both cargo ships and passenger ships the passenger ship report has utilised the same identity numbers to enable reference to be made to the cargo ship section. Those items requiring further explanation are detailed using the identifying prefix P in front of the number.

P001 The Total Number of Persons Provided for by Life Saving Appliances

The total number of persons which may be carried on passenger ships is dependent, apart from the L.S.A. onboard, on the standard of subdivision of the ship and whether the ship is sailing on international or short international voyages. In any case the total number will be confirmed by HQ but may briefly be summarized as follows.

(a) International Voyages
Full boatage i.e. total lifeboat capacity sufficient for all onboard. Lifeboats are required on each side of aggregate capacity as will accommodate not less than 50% of the total number of persons. However, the substitution of lifeboats by davit launched liferafts is permitted provided that there will never be less than sufficient lifeboats on each side of the ship to accommodate $37\frac{1}{2}$% of the total number of persons onboard.

(b) Short International Voyages
Provided the ship satisfies the special subdivision requirements of at least a two compartment standard then these ships are to carry boats, equally distributed on each side of the ship, of aggregate capacity as will accommodate at least 30% of all onboard. The remaining capacity is to be made up by davit launched liferafts equally distributed port and starboard.

Additional davit launchable liferafts of aggregate capacity as will accommodate 25% of the total persons onboard are also required for vessels on both of the above type of voyages.

Passenger ships carrying less than 200 persons (i.e. passenger plus crew) and under 500 gross tons may carry, in lieu of the above mentioned requirements, liferafts on each side of aggregate capacity equal to 150% of the total number of persons onboard. This capacity may be reduced to 100% each side if the liferafts can be readily transferred from side to side. If the rescue boat is also approved for use as a lifeboat it may be included in the aggregate capacity provided the total number of persons for which survival craft is provided is equal to 150% of the total number of persons onboard, on each side of the ship.

Previous to the '83 Amendments for short international voyages the number of lifeboats required was dependent on the registered length of the ship. The liferafts required, together with the boats, to provide accommodation for all onboard were permitted to be of the throw overboard type. Further throw overboard liferafts were also required of total additional capacity equivalent to 10% of the total number of persons for whom there was accommodation in boats. Buoyant apparatus was also required for pre '83 Amendments ships of total capacity sufficient for 3% of the total number of person onboard on international voyages and 5% of the total number of persons onboard on short international voyages.

P002 Motor Lifeboats fitted with Radiotelegraph and Searchlights

Passenger ships engaged on voyages which are not short international voyages where the total number of persons carried is more than 199 but less than 1500 are to have a radiotelegraph installation fitted in at least one of the motor lifeboats. Where the total number of persons carried is more than 1500 such an installation is to be fitted in at least one motor lifeboat on each side. The radio apparatus is to be installed in a designated cabin large enough for the purpose.

Whilst all 1983 Amendments lifeboats are required to be fitted with a searchlight, as detailed in section 019 Item 3.7.40, such a light was only required on pre '83 passenger vessels in at least one motor lifeboat, on each side, when the vessel was carrying more than 30 persons and in one motor lifeboat only when carrying less than 30 persons.

001

Lloyd's Register of Shipping

RECORD OF APPROVED PASSENGER SHIP SAFETY EQUIPMENT

TO MEET THE PROVISIONS OF THE INTERNATIONAL CONVENTION FOR THE SAFETY OF LIFE AT SEA, 1974, AND AMENDMENTS THERETO.

THIS RECORD MUST BE KEPT ON BOARD AT ALL TIMES AND BE AVAILABLE FOR INSPECTION BY A NOMINATED SURVEYOR OR RECOGNISED ORGANISATION.

NAME OF SHIP	SIGNAL LETTERS	NATIONALITY AND PORT OF REGISTRY	GROSS TONNAGE	DATE KEEL LAID†

PREVIOUS NAME AND NATIONALITY	NAMES OF ANY KNOWN SISTERSHIPS

BUILDERS	YARD NUMBER	L.R. NUMBER

CLASS	TYPE OF SHIP

INTERNATIONAL/SHORT INTERNATIONAL* VOYAGES	NUMBER OF PASSENGERS	NUMBER OF CREW

NAME OF OWNERS, MANAGERS OR MANAGING AGENTS	REGISTERED LENGTH	OVERALL LENGTH	DEPTH
	B.P. LENGTH	MAXIMUM BREADTH	SUBDIVISION DRAUGHT

ADDRESS	TYPE OF MACHINERY AND OUTPUT (kW)	AUXILIARIES AND OUTPUT (kW)
	MAIN BOILERS – NUMBER AND TYPE	AUXILIARY BOILERS – NUMBER AND TYPE

P001

NUMBER	THE TOTAL NUMBER OF PERSONS PROVIDED FOR BY LIFE SAVING APPLIANCES IS AND NO MORE VIZ.		
	LIFEBOATS ON PORTSIDE CAPABLE OF ACCOMMODATING	PERSONS	*SELF-RIGHTING/PARTIALLY/TOTALLY ENCLOSED/WITH SELF-CONTAINED AIR SUPPORT SYSTEM/FIRE PROTECTED/OPEN
	LIFEBOATS ON STARBOARD SIDE CAPABLE OF ACCOMMODATING	PERSONS	*SELF-RIGHTING/PARTIALLY/TOTALLY ENCLOSED/WITH SELF-CONTAINED AIR SUPPORT SYSTEM/FIRE PROTECTED/OPEN
	MOTOR LIFEBOATS (INCLUDED IN THE TOTAL LIFEBOATS SHOWN ABOVE).		
P002	INCLUDING		MOTOR LIFEBOATS FITTED WITH RADIOTELEGRAPHY INSTALLATION & SEARCHLIGHT AND
	MOTOR LIFEBOATS FITTED WITH SEARCHLIGHT ONLY		
	RESCUE BOATS (*INCLUDED/NOT INCLUDED IN THE TOTAL LIFEBOATS SHOWN ABOVE), CAPABLE OF ACCOMMODATING	PERSONS	
	LIFERAFTS FOR WHICH APPROVED LAUNCHING APPLIANCES ARE REQUIRED CAPABLE OF ACCOMMODATING	PERSONS	
	LIFERAFTS FOR WHICH APPROVED LAUNCHING APPLIANCES ARE NOT REQUIRED CAPABLE OF ACCOMMODATING	PERSONS	
	LIFERAFTS STOWED FORWARD/AFT CAPABLE OF ACCOMMODATING	PERSONS	
	LIFEBUOYS		
	LIFEJACKETS		
	IMMERSION SUITS		
	THERMAL PROTECTIVE AIDS		

004

SHIP DEFINITION	APPLICABLE TO NEW SHIPS FROM
*NEW/EXISTING SHIP UNDER THE PROVISIONS OF SOLAS 74	25 MAY 1980
*NEW/EXISTING SHIP UNDER THE PROVISIONS OF THE 1981 AMENDMENTS TO SOLAS 74	1 SEPTEMBER 1984
*NEW/EXISTING SHIP UNDER THE PROVISIONS OF THE 1983 AMENDMENTS TO SOLAS 74	1 JULY 1986

†NOTE: IT WILL BE SUFFICIENT TO INDICATE THE YEAR IN WHICH THE KEEL WAS LAID OR WHEN THE SHIP WAS AT A SIMILAR STAGE OF CONSTRUCTION EXCEPT FOR 1952, 1965, 1980, 1981, 1984 AND 1986 IN WHICH CASES THE ACTUAL DATE SHOULD BE GIVEN.

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					1

FORM 2114 (10/87)

*DELETE AS APPROPRIATE

1.0 DOCUMENTATION

1.1 **FIRE CONTROL PLANS** (Ch II-2/20)

1.1.1 To be in the national language. If language is neither English or French a translation into one of these languages is also to be included. ☐

1.1.2 Up-to-date plans permanently exhibited in an accessible location. State language. ☐

1.1.3 Duplicate set of fire plans stored outside deckhouse. ☐

1.2 **MUSTER LIST AND EMERGENCY INSTRUCTIONS** (Ch III/8 & 53)

1.2.1 Muster list including manning of fire parties and emergency procedures in a language understood by the ship's compliment are posted in several parts of the ship, particularly:

1.2.2 In the crews quarters ☐

1.2.3 In the engine room ☐

1.2.4 On the navigating bridge. ☐

1.3 **NAUTICAL PUBLICATIONS** (Ch. V/20)

1.3.1 Adequate and up-to-date charts, sailing directions, lists of lights, notices to Mariners, tide tables and other nautical publications necessary for the intended voyage are provided to the Master's satisfaction. ☐

1.4 **INTERNATIONAL CODE OF SIGNALS** (Ch. V/21)

1.4.1 Copy of current edition is provided. ☐

1.5 **TRAINING MANUAL** (Ch. III/51)

1.5.1 Training manuals containing instructions and information in easily understood terms which illustrate the use of lifesaving appliances and methods of survival are provided on the ship. ☐

1.6 **INSTRUCTIONS FOR ONBOARD MAINTENANCE** (Ch. III/52)

1.6.1 Instructions for onboard maintenance of lifesaving appliances illustrated where possible are provided. ☐

1.7 **OPERATING INSTRUCTIONS** (Ch. III/9)

1.7.1 Poster or signs are provided on or in the vicinity of survival craft and their launching controls which illustrate their use. ☐

005

2.0 SAFETY OF NAVIGATION (Ch. V/12)

2.1	SHIPBORNE NAVIGATIONAL EQUIPMENT	*TYPE AND SERIAL NUMBER	*MANUFACTURER
2.1.1	Standard Magnetic Compass		
2.1.2	Steering Magnetic Compass or reflector to the steering position		
2.1.3	Means of communication between Standard Compass and normal navigational control position		
2.1.4	Means of taking bearings through 360°		
2.1.5	Magnetic Compass table of residual deviation		
2.1.6	Spare Magnetic Compass		
2.1.7	Gyro Compass		
2.1.8	Heading information at emergency steering position		
2.1.9	Radar (Number One)		
2.1.10	Radar (Number Two, if required)		
2.1.11	Radar plotting facilities		
2.1.12	Automatic Radar Plotting Aid (ARPA)		
2.1.13	Echo sounder		
2.1.14	Speed and distance indicator		
2.1.15	Rudder angle indicator		
2.1.16	Propeller revolution counter		
2.1.17	Propeller pitch and mode indicator		
2.1.18	Rate of turn indicator		
2.1.19	Radio direction finder		
2.1.20	2182 kHz homing on RDF		

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					2

2.2 **AUTO PILOT** (Ch. V/19)

2.2.1 Is the autopilot provided with an emergency source of power? ☐

2.2.2 Where an autopilot is fitted, clear instructions are provided at the control console on change-over procedure from automatic to manual steering and vice versa. ☐

2.2.3 Is the autopilot fitted with an off-course alarm? ☐

2.3 **STEERING GEAR** (Ch. V/19)

2.3.1 Simple operating instructions with a block diagram showing the change-over procedure for remote steering gear control systems and steering gear power units are permanently displayed on the navigating bridge and in the steering gear compartment. ☐

006 2.4 **SIGNALLING APPARATUS** (Ch. V/11) (And revised Collision Regulations 1972)

	APPARATUS	NUMBER	DESCRIPTION	LOCATION
2.4.1	Daylight signalling lamps			
	Source of power	–		
2.4.2	Forecastle bell			
2.4.3	Gong (with striker)			
2.4.4	Ship's whistle (Type & Serial No.) †			
2.4.5	3 Black Ball shapes			
2.4.6	1 Black Diamond shape			
2.4.7	Cylindrical shape*			

2.4.8 † If only one electrically powered whistle is fitted it is provided with both main and emergency power supply ☐

007 2.5 **NAVIGATION LIGHTS** (Revised Collision Regulations 1972)

2.5.1 Application of revised Collision Regulations 1972.
The following information may be obtained from plans, if available. See also diagram on page 4.

2.5.2	Horizontal distance in metres	1	Foremast light abaft top of stem	
		2	Between foremast and mainmast lights	
2.5.3	Vertical height in metres above waterline in condition of maximum trim by stern	1	Foremast light	
		2	Mainmast light	
2.5.4	Vertical height in metres above uppermost continuous deck	1	Sidelights	
		2	Foremast light	
		3	Mainmast light	

	LIGHT	OIL	ELECTRIC	MILES RANGE	TWO TIER TYPE	POWER SOURCE
2.5.5	Fore Masthead					
2.5.6	Main Masthead					
2.5.7	Port side					
2.5.8	Starboard side					
2.5.9	Stern					
2.5.10	Towing					
2.5.11	Anchor (1)					
2.5.12	Anchor (2)					
2.5.13	NUC (1)					
2.5.14	NUC (2)					

2.5.15 At least one complete set of spare bulbs is provided. ☐

2.5.16 Sidelights fitted with inboard screens painted matt black. ☐

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					3

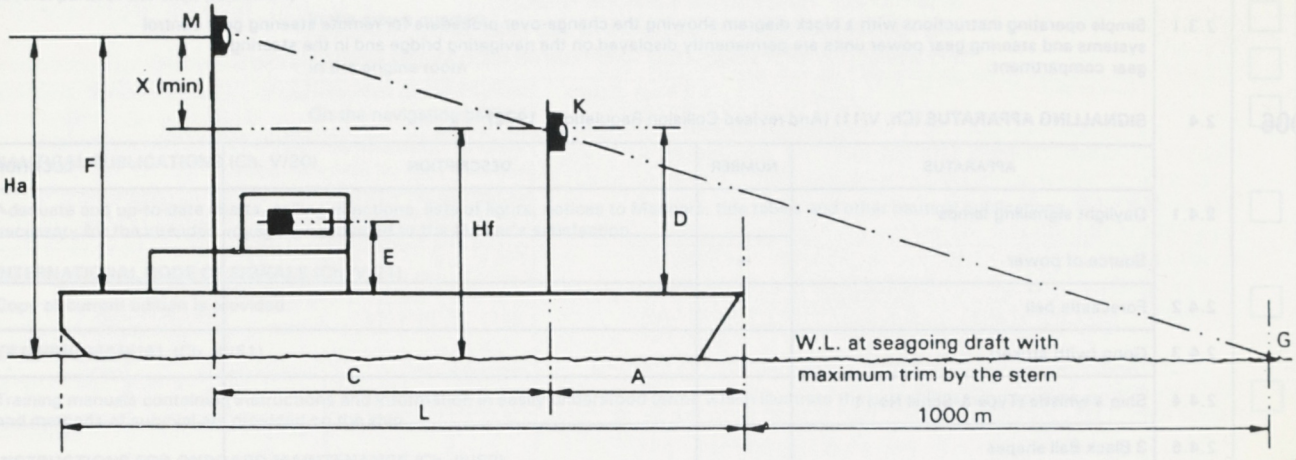
2.6 **POWER SOURCE** (Ch. II-1/41 & 43)

2.6.1 Indicate main supply (M) ☐

2.6.2 Indicate emergency supply (E) ☐

2.6.3 Indicate main and emergency supply (ME) ☐

2.7 **NAVIGATION LIGHT POSITION CHECK**



L = Length overall

A = Not more than 0 · 25 L [Annex I 3(a)]

B = Greatest breadth of vessel

C = Not less than 0 · 5 L need not be more than 100 m [Annex I 3(a)]

D = Not less than 6 m or B if B is more than 6 m but D need not be greater than 12 m [Annex I 2(a)(i)]

Sidelights

(a) Not in front fwd masthead light [Annex I 3(b)]

(b) At or nearside of vessel recommend not more than B/10 inboard [Annex I 3(b)]

(c) Inboard screens to be painted matt black [Annex I (5)]

E = Not more than 0 · 75 D. (D = height of fwd masthead light) [Annex I 2(g)]

F = D + 4 · 5 m minimum and such that in all normal conditions of trim the after light will be seen over and separate from the forward light at 1000 m forward of the stern at sea level
(Allow 450 mm (18") for depth of lantern) [Annex I 2(a)(ii) and 2(b)]

Hf = Height to centre of forward masthead light above the waterline in normal seagoing condition with maximum trim by the stern

Ha = Height to centre of aft masthead light above the waterline in normal seagoing condition with maximum trim by the stern

(Recommend mainmast light be positioned not less than 450 mm above point line where GK produced intersects mainmast in order that mainmast light be seen separate from and above the foremast light from point G with vessel in condition with maximum trim by stern.)

$$\frac{X\ (\text{minimum})}{C} = \frac{Hf}{A + 1000} \therefore X\ \text{Min} = \frac{C.Hf}{A + 1000} =$$

Actual 'X' = (F – D) = ( ) =

NB: With vessel on even keel and upperdeck assumed parallel to waterline (no sheer, no camber) F – D should not be less than 4 · 5 m.

2.7.1 Do the positions of the Navigation Lights comply with 1972 Collision Regulations? Yes ☐ No ☐

2.8 **PILOT LADDERS AND MECHANICAL PILOT HOISTS** (Ch. V/17)

008 2.8.1 Pilot ladder provided for embarkation and disembarkation of pilots with provisions for adequate overside lighting at night ☐

2.8.2 Lifebuoy with light and a heaving line located close by are provided ☐

2.8.3 Bulwark ladder*, OR ☐

2.8.4 Hinged rail section* ☐

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					4

009

2.8.5	Mechanical Pilot Hoist (if provided) (Ch. V/17)	
	MAKE	
	SOURCE OF POWER	NO. AND MATERIAL OF FALLS
	LENGTH	CONSTRUCTION AND SIZE

010

2.8.6	Accommodation Ladder. (Only required for use by pilot when distance from sea level to the point of access to the ship is more than 9 metres in any seagoing conditions.)	
	MAKE	
	LENGTH	MATERIAL

3.0 LIFE-SAVING APPLIANCES

3.1 ROCKETS AND SIGNALS (Ch. III/6 & 17)

		STORAGE LOCATION
011	3.1.1 Line throwing appliances with 4 rockets and lines	
012	3.1.2 12 parachute distress signals	
	3.1.3 Additional rockets and signals if provided	

3.2 COMMUNICATIONS (Ch. III/6)

		MAKE, TYPE AND SERIAL NUMBER	SET NUMBER	LOCATION
013	3.2.1 Survival craft portable radio		1	
	3.2.2		2	
	3.2.3		3	
014	3.2.4 Survival craft/emergency position indicating radio beacon (min 2) OR Radar transponder in lieu*		1	
			2	
015	3.2.5 Two way radiotelephone apparatus (min 3)		1	
			2	
			3	

3.2.6 On board means are provided for two-way communication between emergency control stations, muster and embarkation stations and strategic positions on the ship. ☐

3.3 SURVIVAL CRAFT, MUSTER, LAUNCHING AND EMBARKATION ARRANGEMENT, LAUNCHING STATION, STOWAGE OF SURVIVAL CRAFT AND RESCUE BOAT (Ch. III/11, 12, 13, 14 & 15)

3.3.1 Muster station provided close to embarkation station. ☐

3.3.2 Muster and embarkation station, survival craft and rescue boat launching appliance area of water into which survival craft and rescue boats are launched, provided with adequate lighting. ☐

3.3.3 Lighting also supplied from emergency source of power. ☐

3.3.4 Muster and embarkation stations are arranged to enable stretcher cases to be placed in survival craft. ☐

(a) An embarkation ladder in single length from the deck to the lightest seagoing waterline under unfavourable trim and list, is provided at each launching station ☐

OR

(b) one at every two adjacent launching stations. ☐

3.3.5 Launching station arranged to be clear of propeller and steeply overhanging portions of the hull. ☐

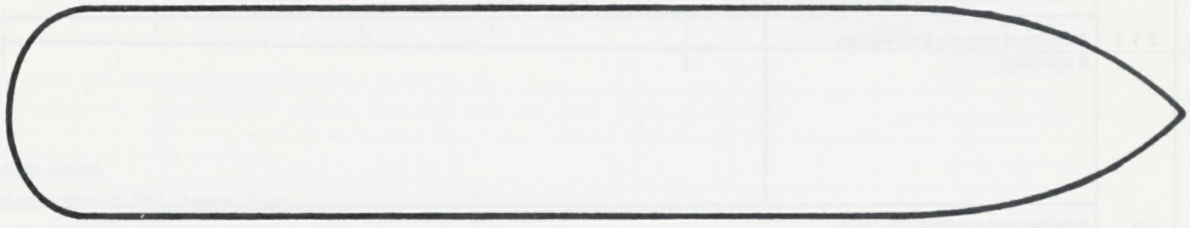
3.3.6 Survival craft and rescue boats are stowed so that they and their arrangement will not interfere with each other. ☐

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					5

	3.3.7	Means are provided for preventing discharge of water into survival craft.	☐
	3.3.8	If there is a danger of survival craft being damaged by ship's stabilizer fins, means powered by an emergency source of power are provided to bring the fins inboard.	☐
	3.3.9	A stabilizer fin position indicator is provided on navigation bridge.	☐
	3.3.10	At least two lifelines are fitted to davit spans.	☐
	3.3.11	Means are provided for holding survival craft against the ship's side.	☐
P003	3.3.12	Public address system fitted with means to overide all other broadcasts & facility for addressing crew only. OR	☐
	3.3.13	Public address system and separate special alarm, which may be part of ship's general alarm, but is capable of being sounded independently of the alarm to the passenger spaces.	☐

P004 3.4 **LOCATION OF SURVIVAL CRAFT AND RESCUE BOATS**

Indicate superstructures and positions of lifeboats, liferafts and rescue boats. Indicate on sketch: motor (M); mechanically propelled (MP); pulling (P); freefall (F); liferafts (LR); rescue boats (RB). Number boats from forward, odd numbers starboard side, even numbers port side.



021 3.5 **LIFEBOATS** (Ch. 111/41)

NO.	NO. OF PERSONS	DIMENSIONS (L × B × D ft/m)	TYPE (SEE BELOW)	MATERIAL	MANUFACTURER	APPROVED BY
1 (SS)						
3						
5						
7						
9						
11						
13						
15						
17						

Type: Totally enclosed/Partially enclosed/Self-righting partially enclosed/Open/Motor/Other Motor/Mechanically propelled/Pulling

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					6

NO.	NO. OF PERSONS	DIMENSIONS (L × B × D ft/m)	TYPE (SEE BELOW)	MATERIAL	MANUFACTURER	APPROVED BY
2 (PS)						
4						
6						
8						
10						
12						
14						
16						
18						

3.5.1	Indicate lifeboat(s) used as rescue boats	No	PS	No	SS
3.5.2.	Indicate number of persons in rescue boats if less than the above table		PS		SS
3.5.3.	Indicate lifeboat(s) fitted with fixed radio installations	No	PS	No	SS
3.5.4.	Indicate lifeboat(s) used as passenger tenders	Nos	PS		
		Nos	SS		

017 3.5.5. Simultaneous release mechanism for releasing lower fall blocks from lifting hooks fitted ☐

3.5.6. The hook release mechanism is able to operate:

(a) When the lifeboat is waterbourne or no load on the hooks, and ☐

(b) with a load on the hooks of 1 · 1 times the total mass of the lifeboat with its full compliment of persons and equipment ☐

3.5.7. The 'on load' capability is adequately protected against accidental or premature release ☐

P005 3.6 **LAUNCHING APPLIANCES** (Ch III/48)

3.6.1

DAVIT NUMBER	MAKER AND TYPE	S.W.L.

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					7

3.6.2	WINCH NUMBER	MAKER AND TYPE	S.W.L.

3.6.3	Falls	ROPE	LENGTH AND SIZES
		WIRE ROPE: CORROSION RESISTANT ☐ ROTATION RESISTANT ☐	BREAKING LOADS
		CONSTRUCTION	

3.7 **MEANS OF LOWERING LIFEBOATS**

3.7.1 The launching appliances are capable of recovering the rescue boats with a maximum of persons onboard at a rate of not less than (Indicate maximum numbers and rate (Minimum recovery rate · 3 m/sec))

3.7.2 Where appropriate confirm that:

At least two lifelines are fitted to davit spans ☐

Means are provided for holding survival craft against ship's side ☐

P006 3.7.3 Lifeboats/Rescue boats are fully equipped in accordance with the Regulation applicable to:

Existing ships ☐

New ships from 1.7.86 ☐

022 3.8 **MARKING OF BOATS**

Dimensions and number of persons it is permitted to carry permanently marked thereon ☐

Name and Port of Registry of the ship to which lifeboat belongs painted on each side of the bow ☐

025 3.9 **LIFERAFTS** (Ch III/38.39 & 40)

NO.	DESCRIPTION	MAKERS NAME AND SERIAL NUMBER	NO. OF PERSONS	DAVIT LAUNCHED YES/NO	APPROVED BY

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					8

027 /031

3.10 **LIFERAFT/RESCUE BOAT LAUNCHING APPLIANCES**

3.10.1 CRANE/DAVIT	MARK AND TYPE	S.W.L.

3.10.2 Falls

ROPE	LENGTH AND SIZES
WIRE ROPE: CORROSION RESISTANT ☐ ROTATION RESISTANT ☐	BREAKING LOADS
CONSTRUCTION	

3.10.3 Each inflatable liferaft, if lashed, is fitted with a hydrostatic release ☐

3.10.4 The davit launchable liferaft release arrangement is protected against premature release during lowering ☐

028

3.11 **MARKING OF INFLATABLE LIFERAFTS** (Ch. 111/39)

3.11.1 Each liferaft is marked with:

The date of the last service	☐	SOLAS A Pack	☐
Maker's name or trademark	☐	Length of Painter	☐
Serial Number	☐	The maximum permitted stowage height above waterline	☐
Name of Approving Authority	☐	At each entrance the number of persons it is certified to accommodate	☐

P007

3.11.2 Are the liferafts fully equipped in accordance with the Regulations applicable to:

Existing Ships ☐

New ships from 1.7.86 ☐

3.11.3 For ships engaged on short international voyage indicate numbers of liferafts with reduced equipment in accordance with Chapter III/39·5·3 ☐

P008

3.12 **BUOYANT APPARATUS** – Applicable only to existing ships prior 1.7.86 and New Greek Flag Ship

NO.	NO. OF PERSONS	TYPE AND MATERIAL	LOCATION

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					9

3.13 **OTHER LIFESAVING APPLIANCES** (Ch. III/7 & 21)

	NO.	MAKE AND TYPE
P009 033 Life jackets with whistle attached		
034 For ships engaged on international voyages – life jackets with light		
035 Lifebuoys with lights and smoke signals		
Capable of quick release from bridge		
Lifebuoys with self-lighting lights only		
Lifebuoys with buoyant lifelines		
Lifebuoys without attachments		
036 Immersion suits*		
Thermal protective aids*		

* Not required for persons to be accommodated in totally or partially enclosed lifeboats or if the ship is constantly engaged on voyages in warm climates.

037 3.13.1 All survival craft, lifebuoys and lifejackets are fitted with retro-reflective material. ☐

4.0 ## FIRE EXTINGUISHING ARRANGEMENTS (Ch. II/2)

P010 4.1 **PUMPS, FIRE MAIN, HYDRANTS, HOSES, Etc.** (Ch. II-2/4)

Fire pumps and fire main.

	FIRE PUMPS	NO.	CAPACITY	PRIME MOVER	LOCATION
4.1.1					
4.1.2					
4.1.3					
4.1.4					

4.1.5 Fire main diameter.

040 4.1.6 Location of machinery space fire main risers isolating valves.

4.1.7 Relief valves fitted if pumps capable of developing pressure exceeding the design pressure of service pipe. ☐

4.1.8 Relief valves locations.

4.1.9 If applicable, state which pump(s) is/are:
a) Remote controlled from bridge or fire control station

OR

4.1.10 b) Capable of maintaining permanent pressurisation of firemain system.

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					10

041

4.2 **HYDRANTS** (Ch. II-2/4)

	LOCATION	NUMBER	DIAMETER	TYPE OF COUPLING
4.2.1	Machinery spaces			
4.2.2	Accommodation			
4.2.3	Weather decks			
4.2.4	Other spaces			

042

4.3 **HOSES AND NOZZLES** (Ch. II-2/4)

	LOCATION	NUMBER	DIAMETER	LENGTH	MATERIAL	SPRAY/JET NOZZLE WITH SHUT-OFF
4.3.1	Machinery spaces					
4.3.2	Accommodation					
4.3.3	Weather decks					
4.3.4	Other spaces					

043

4.4 **SAND BOXES AND SCOOPS** (Ch. II-2/7) If provided

	NUMBER	LOCATION(S)
4.4.1		

044

4.5 **INTERNATIONAL SHORE CONNECTION** (Ch. II-2/19)

	NUMBER	LOCATION(S)
4.5.1		

045

4.6 **FIRE EXTINGUISHERS** (Ch. II-2/6 & 7)

	ITEM	LOCATION	NUMBER	TYPE	CAPACITY	NUMBER OF SPARE CHARGES†
4.6.1	Portable extinguishers	Machinery spaces				
4.6.2		Accommodation spaces				
4.6.3		Service spaces				
046 4.6.4	Portable Foam applicator units	Machinery spaces				
		Other spaces				
4.6.5	Non-portable extinguishers					

P011 4.6.6 In passenger ships carrying more than 36 passengers each machinery space of category 'A' provided with 2 water fog applicators ☐

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					11

FORM 2114-10 (10/87)

† ALTERNATIVE DUPLICATE EXTINGUISHERS MAY BE PROVIDED

047 4.7 **FIREMAN'S OUTFITS** (Ch. II-2/17)

Number of fireman's outfits (each comprising protective suit, boots, gloves, rigid helmet, safety lamp, axe, lifeline, safety belt harness and self-contained breathing apparatus)

located on decks

In addition: Number of sets of personal equipment (each comprising protective suit, boots, gloves, rigid helmets, safety lamps and axe)

located on decks

Type, manufacturer, capacity and functioning period of self-contained breathing apparatus

Spare cylinders supplied for breathing apparatus OR ☐

approved recharging facilities provided with at least one spare cylinder per self-contained breathing apparatus ☐

4.8 **SMOKE HELMET OR SMOKE MASK WITH AIR PUMP AND HOSE, IF PROVIDED**

NO.	MAKE	APPROVAL AUTHORITY

P011 Water fog applicator provided for each pair of breathing apparatus ☐

048 4.9 **FIXED FIRE EXTINGUISHING & PROTECTION SYSTEMS**

NO.	SPACE PROTECTED	CO_2	HALON	FIXED FOAM	FIXED PRESSURE WATER SPRAYING	AUTOMATIC SPRINKLER SYSTEM	DRY POWDER	INERT GAS SYSTEM	OTHERS

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					12

FORM 2114-11 (10/87)

DETAILS OF FIXED FIRE EXTINGUISHING AND PROTECTION SYSTEMS

049 4.10 CO_2 System(s) (Ch. II-2/5)

PROTECTED SPACES	STORAGE CONTAINERS			LOCATION OF REMOTE CONTROL STATION	TYPE OF AUDIBLE ALARM	LOCATION OPERATING INSTRUCTIONS POSTED
	NUMBER	CAPACITY EACH	LOCATION			

050 4.11 **HALOGENATED SYSTEM(S) (HALON)** (Ch. II-2/5)

PROTECTED SPACES	1301/1211	STORAGE CONTAINERS			LOCATION OF REMOTE CONTROL STATION*	TYPE OF AUDIBLE ALARM	LOCATION OF OPERATING INSTRUCTIONS
		NUMBER	CAPACITY EACH	LOCATION			

* Indicate automatic (A) or manual (M) release of system.

N.B. Only secondary systems are permitted to be fitted with automatic release (See Ch. II-2/5.3.4)

Automatic stop for all ventilation fans serving the protected space is provided. ☐

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					13

FORM 2114-12 (10/87)

051 4.12 **FIXED FOAM SYSTEM(S)** (Ch. II-2/8, 9 & 61)

DETAILS		PROTECTED SPACE	
		ENGINE/BOILER ROOM	OTHER SPACES
Foam	Type		
	Manufacturer		
	Quantity		
	Application Rate		
	Concentration Ratio OR Expansion Ratio		
Pump	Type		
	Location		
	Capacity		
	Location of Controls		
Location of Foam Tank			
Location of Controls			

Manufacturer's service instruction manual is provided. ☐

052 4.13 **FIXED PRESSURE WATER SPRAYING SYSTEM(S)** (Ch. II-2/10)

PROTECTED SPACES	PUMPS*		NOZZLES TYPE AND MAKE	APPLICATION RATE LITRES/Sq.M	LOCATION OF REMOTE CONTROL STATION
	LOCATION	CAPACITY			

* If Diesel Driven	MEANS OF STARTING	FUEL TANK CAPACITY
* If Electrically Driven	SOURCE OF EMERGENCY POWER	LOCATION OF EMERGENCY POWER

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					14

053 4.14 **AUTOMATIC SPRINKLER, FIRE DETECTION AND FIRE ALARM SYSTEM** (Ch. II-2/12) See also 5.1 method IIC

PROTECTED SPACES	AUTOMATIC INDEPENDENT POWER PUMP†		SOURCES OF POWER	SECTION PLAN AND INSTRUCTION PROVIDED	LOCATION OF STOP VALVES
	LOCATION	CAPACITY			

† Electrically Driven Pump	SOURCE OF EMERGENCY POWER	LOCATION OF EMERGENCY POWER

Fresh water tank capacity

Sprinkler heads

TYPE	MANUFACTURER	TOTAL NUMBER OF SPARES

Location of automatic audible and visual alarms for each section of sprinklers

Location of section isolating stop valves

Are section isolating stop valves fitted with means of locking? ☐

Location of cross-connection valve to firemain

056 4.15 **GALLEY EXHAUST PROTECTIVE SYSTEM** (Ch. II-2/16.7.4)

Type of system

Number of cylinders

Total capacity

Location of controls

Location of exhaust fan shut-off control(s)

4.16 **OTHER SYSTEM(S) – GIVE DETAILS**

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					15

FORM 2114-14 (10/87)

5.0 FIRE PROTECTION, FIRE DETECTION AND ALARM SYSTEMS

P012 5.1 **STRUCTURAL FIRE PROTECTION** (See approved fire control plan for category of structural fire protection and location of fire doors)

SOLAS 1948/1960: Method I ☐ Method II ☐ Method III ☐

SOLAS 1960 (Part 'H') ☐ SOLAS 1974 ☐ SOLAS 1974. 81 Amendments ☐ SOLAS 1974. 83 Amendments ☐

5.1.1 Main vertical fire zone bulkheads at frame No.

5.1.2 Main horizontal fire zones at (decks)

P013 5.1.3 Fire doors in M.V.Z. bulkheads, stairway enclosures, escapes etc., capable of remote release ☐

Location of releases

5.1.4 Other fire doors, method of release

P014 5.2 **FIXED FIRE DETECTION AND FIRE ALARM SYSTEMS** (Ch. II-2/13) (*See* Page 15, 4.14)

(*See* Approved Fire Control Plan for locations of detectors and alarms)

FIRE DETECTOR MAKE AND TYPE	NUMBER	SPACE COVERED

FIRE ALARM MAKE AND TYPE	NUMBER	SPACE COVERED

Control panel location

Indicator unit(s) location(s)

Visual and audible signal at control panel for fault in power supply or electric circuits ☐

Fire and/or general alarm (audible) automatically activated throughout accommodation, service spaces, control stations, machinery spaces if response to fire signal not acknowledged within 2 minutes ☐

Manually operated fire alarm call points located throughout accommodation spaces, service spaces and control stations ☐

Suitable instructions and components spares for testing and maintenance provided ☐

Automatic release arrangements for self-closing fire doors provided at the control panel ☐

058 5.3 **GENERAL ALARM** (Ch. III/50)

Means of abandon ship warning

Location of control(s)

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					16

FORM 2114-15 (10/87)

6.0 EMERGENCY CONTROL/SPECIAL ARRANGEMENTS IN MACHINERY AND ACCOMMODATION SPACES (Ch. II-2/11)

059 6.1 **MEANS FOR STOPPING VENTILATION FANS AND PUMPS AND SHUTTING OFF OIL FUEL SUCTION PIPES**

EQUIPMENT		MEANS AND LOCATIONS
Ventilation Fans	Accommodation	
	Machinery Spaces	
Oil Fuel Units		
Oil Fuel Transfer Pump		
Boiler Fans		
Oil Fuel and Lub. Oil Tank Valves		
Others		

The following are able to be closed from outside the space concerned:

a) Ventilator dampers ☐

b) Funnel openings ☐

c) Skylights ☐

d) Doorways ☐

e) Tunnel door ☐

7.0 EMERGENCY ELECTRIC POWER (Ch. II-1/43, 44)

060 7.1	Source of Power Including Rating or Capacity and Location	
7.2	Location of transitional source	
7.3	If Generator, Means of Starting	
7.4	Services Supplied	
061 7.5	Location of Emergency Switch board	

8.0 SPECIAL ARRANGEMENTS FOR CERTAIN SHIPS

8.1 **PERIODICALLY UNATTENDED MACHINERY SPACE** (Ch. II-2/14)

Fire detection and fire alarm system fitted ☐

Audible and visual alarm fitted on the navigation bridge ☐

Audible and visual alarm fitted in engineer officers' office ☐

Location where a responsible crew member is on duty

Location of remote controls for sea inlets, discharges below the waterline or bilge injection where installed in periodically unattended machinery space

8.2 **SPECIAL CATEGORY SPACES** (Ch. II-2/37-38) (And other cargo spaces intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion).

Fire detection and fire alarm system fitted ☐

Fire extinguishing arrangements provided ☐

Special drainage/pumping system provided, OR ☐

relevant stability information contained in Stability Booklet approved — DATE — PLACE

Portable extinguishers at each access ☐

Each Ro/Ro cargo space provided with at least 3 water fog applicators and 2 portable foam applicators ☐

Power ventilation system fitted ☐

Number of air changes per hour

Indication of loss of ventilating capacity at the navigating bridge ☐

Position of ventilation shut-down and closing arrangements in case of fire

Number of portable gas detection units

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					17

P015

9.0 BILGE PUMPING ARRANGEMENT (Ch. II-1)

9.1 Bilge main diameter and material

9.2 **BILGE PUMPS**

PUMP	LOCATION
Pump with emergency power supply	
Direct suction conn to (Pump)	

9.3 **DISTRIBUTION BOXES, COCK & VALVES**

SUCTION	LOCATION OF OPERATION FROM ABOVE BHD DECK
Engine Room	
Auxiliary Spaces	
Boiler Room	
Shaft Tunnel	
Other Spaces	

9.4 **EMERGENCY BILGE PUMP AND VALVES** – If applicable

	LOCATION	LOCATION OF CONTROLS
Emergency bilge pump		
Emergency bilge valves		

9.5 Self closing cocks fitted on sounding pipes in:

Engine Room ☐; Boiler Room ☐; Shaft Tunnel ☐; Other Spaces ☐

P016

10.0 BULKHEAD VALVES ON OTHER SYSTEMS

SYSTEM	LOCATION OF REMOTE OPERATION

P017

11.0 WATERTIGHT BULKHEAD DOORS

NO	CLASS	MANUFACTURER	LOCATION	LOCATION OF CONTROLS		
				BRIDGE	ABOVE B.D.	LOCAL

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					18

FORM 2114-17 ((10/87)

11.2 Type of operation:

Electric ☐; Hydraulic ☐; Manual ☐

11.3 **EMERGENCY STATIONS**

NO.	LOCATION	NO. OF DOORS CONTROLLED

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					19

12.0 **ADDITIONAL INFORMATION**

ITEM* NUMBER	

SURVEYOR'S SIGNATURE	PORT	DATE PAGE COMPLETED	L.R. NUMBER	REPORT NUMBER	PAGE
					20

FORM 2114-19 (10/87)

13.0 EQUIPMENT RENEWALS, ALTERATIONS AND/OR ADDITIONS EFFECTED SINCE THE RECORD WAS PREPARED

ITEM NUMBER	DESCRIPTION	SURVEYOR	PORT	DATE

P003 Public Address System

Such a system is necessary for the efficient every day running of the ship. In order to avoid causing unnecessary concern among the passengers the system must have a facility provided to summon and/or address the crew only without disturbing the passengers.

P004 Lifeboats

Whilst the format of this section of the report form is different to the corresponding section of the cargo ship report the information required is virtually the same and reference should be made to sections 016 and 017.

P005 Launching Appliances

The basic requirements for passenger ship launching appliances are as for those on cargo ships with the proviso that complete abandonment of the ship must be completed within 30 minutes. Passenger ship survival craft are to be capable of being boarded either from their stowed position or the embarkation deck, *but not both*. Rescue boats, however, are to have an embarkation facility at both positions. Reference should be made to section 018.

P006 Lifeboat/Rescue Boat Equipment

For existing ships, i.e. pre 1983 Amendments, the equipment in lifeboats should be as indicated in the previous '74 SOLAS S.E.1.

Equipment for '83 lifeboats and rescue boats is to be in accordance with that indicated on the latest cargo ship S.E.1. (See sections 019 and 030).

Certain items of lifeboat equipment may, at the discretion of the flag administration, be omitted from lifeboats on ships engaged on short international voyages viz:-

On pre '83 ships:

(i) mast, stays and sails
(ii) food rations
(iii) daylight signalling mirror
(iv) jack-knife
(v) fishing tackle

On '83 ships:

(i) food rations
(ii) fishing tackle

P007 Liferaft Equipment

The liferaft equipment list in the cargo ship S.E.1 may be used for checking the corresponding equipment on passenger ships. As with lifeboats, however, certain items of this equipment may be dispensed with in liferafts, at the discretion of the administration for ships engaged on short international voyages. When equipment omission has been agreed, the container of inflatable liferafts is to be marked "SOLAS B PACK" as apposed to "SOLAS A PACK" for which compliance with the full list is required.

The items that an administrations may exempt are:

(i) tin openers
(ii) two rocket parachute flares
(iii) three hand flares
(iv) one buoyant smoke signal
(v) fishing tackle
(vi) food ration
(vii) water ration
(viii) drinking vessels
(ix) sea sickness tablets
(x) survival instructions
(xi) instructions for immediate action
(xii) thermal protective aids

P008 Buoyant Apparatus (required on pre '83 amendments ships only)

Each buoyant apparatus should not exceed 180 Kgs in weight and is to be stowed in a position from where it can easily be thrown into the water. The type of apparatus is generally found on the uppermost open deck in a position where it can float free. It is to be effective and stable when floating either way up.

P009 Lifejackets

Whilst lifejackets are to be fitted with lights on all new passenger ships, and on existing passenger ships engaged on international voyages by 1 July 1991 lifejackets with lights are not required to be provided on passenger ships engaged on short international voyages. See also section 033 and 034.

The number of lifejackets on passenger ships shall be sufficient for all on board plus an additional five per cent of that number. The lifejackets are generally distributed throughout the crew and passenger cabins whilst the five per cent additional lifejackets should be located at the muster or survival craft embarkation stations. For ships engaged on short international voyages, where all passengers have not been allocated cabins, passenger lifejackets are generally stowed at muster stations whilst the crew lifejackets will probably be found in crew cabins.

Additional childrens' lifejackets, suitable for a person less than 32kgs are also to be available on board all passenger ships equal to at least ten per cent of the total number of passengers.

P010 Pumps, Firemain, Hydrants, Hoses, etc.

At least three independently driven fire pumps are required on passenger ships of 4000 G.T. and over and are to be so arranged that a fire in any one compartment will not put all the fire pumps out of action. This may be achieved by locating at least one pump in a separate compartment. Passenger ships of less than 4000 G.T. are to be fitted with at least two fire pumps. It should be noted that all fire pumps are of equal status i.e. there is no emergency fire pump. If fire pumps are electrically driven, then one of the required pumps is to be driven from an emergency source of power through the emergency switchboard. This pump should not be located in a main generating station.

The fire main should be pressurized such that at least one effective jet of water is immediately available from any internal hydrant. This may be achieved by a hydrophore system or small pump maintaining fire main pressure. The pressure drop when opening a hydrant should cause the automatic starting of one of the main fire pumps.

The arrangement of hydrants is to be such that two jets of water, not from the same hydrant, can reach any part of the ship normally accessible to passengers and crew and any part of any cargo space when empty. One of these jets should be from a single length of hose. This fire fighting capability is to be achieved with all watertight doors and main vertical zone fire doors closed. At least one hose is to be supplied for each hydrant.

P011 Water Fog Applicators

Two of these applicators (See fig 16) are to be provided in each machinery space of category 'A' and with each pair of breathing apparatus.

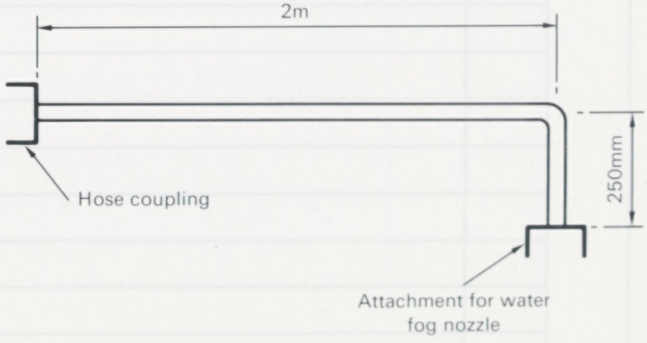


Fig 16

P012 Structrual Fire Protection

Ships built to 1948 and 1960 SOLAS incorporated structural fire protection according to one of the following methods:-

Method I – The construction of internal divisional bulkheading of "B" Class divisions generally without the installation of a detection or sprinkler system in the accommodation and service spaces.

Method II – The fitting of an automatic sprinkler and fire alarm system for the detection and extinction of fire in all spaces in which a fire might be expected to originate, generally with no restriction on the type of internal divisional bulkheading in spaces so protected.

Method III – A system of subdivision within each main vertical zone using "A" and "B" Class divisions according to the importance, size and nature of the various compartments, with an automatic fire detection system in all spaces in which a fire might be expected to originate, together with restricted use of combustible and highly inflammable materials and furnishings, but generally without the installation of a sprinkler system.

Whilst not obligatory IMO Resolution A.122 (V) dated 25th October 1967, commonly known as "Part H" was often used as a basis for fire protection, detection and extinction on 1960 SOLAS ships. It was the virtual forerunner of Chapter II-2 of SOLAS 74.

SOLAS 74 Chapter II-2 introduced new statutory concepts in structural fire protection and required passenger ships to be fitted with an automatic fire detection system of either an electric or automatic sprinkler type. The boundary insulation values between adjacent spaces was determined according to the type of fire detection system fitted and the content/use of each space.

The 1981 Amendments to SOLAS '74 incorporated a complete re-write of Chapter II-2 and introduced some refinements e.g. more specific requirements for Halon systems, ventilation, bulkhead penetrations, a maximum calorific value for combustible veneers and more specific requirements with respect to the location of the main switchboard.

The 1983 Amendments introduced further modifications to Chapter II-2 which include a requirement for all new ships that have an automatic sprinkler system installed also to be fitted with a smoke detection system in corridors, stairways and escape routes in accommodation spaces.

P013 Fire Doors

Fire doors may be either of hinged or sliding type and may comprise one or two leaves. If the fire door is not normally locked closed it should be fitted with a self closing device. Those fire doors which in normal service remain open will probably be held in this position by an electro magnet with a local release control. These doors are also to be capable of remote release from the main fire control station and/or the navigating bridge where an indicator board is to be fitted in order to confirm the operation of each door. Fire doors are to be capable of being closed against an inclination of 3 degrees. At surveys the following procedures should be dealt with:-

(i) Check mimic diagram on bridge and/or fire control station, confirm all lights working.
(ii) Close all doors from central control and confirm successful operation from mimic panel.
(iii) Operate all doors from local switches.
(iv) On large doors confirm that the damping arrangements are effective against excessive speed of closure which may cause injury.
(v) Confirm double leaf doors close in the correct sequence.
(vi) Confirm door openings remain free from obstruction.
(vii) Check that any recently laid carpet has not been run under the door into the next space.

P014 Fixed Fire Detection and Fire Alarm Systems

Ships carrying more than 36 passengers are required to maintain an efficient fire patrol system in order to ensure an outbreak of fire may be promptly detected. Each member of the patrol is to be familiar with the arrangement of the ship and well drilled in the location and operation of equipment he may be required to use.

It is normal to have a system of verifying the completion of fire patrols, which should be half hourly, and this may be done by the use of time key clocks or a patrol log book being maintained on the bridge.

P015 Bilge Pumping Arrangement

A minimum of three pumps are required for bilge pumping services and together with the bilge main, are generally located inboard of the B/5 line where, from the SOLAS point of view, they are considered immune from collision damage. The pumps must be distributed throughout the ship so as to ensure at least one pump is always available for use in all flooding conditions the ship is required to withstand. This can be achieved if one of the required bilge pumps is of a submersible type with an emergency source of power from above the bulkhead deck or the bilge pumps and their sources of power are distributed throughout the length of the ship so that at least one pump is always available in an undamaged compartment.

Distribution boxes, cocks and valves in connection with the bilge pumping system should be so arranged that, in the event of flooding, one of the bilge pumps may be operative on any compartment. In addition, damage to a pump or its pipe connecting to the bilge main outboard of a line drawn at one fifth of the breadth of the ship should not put the bilge system out of action. If there is only one system of pipes common to all the pumps then the necessary valves for controlling the bilge suctions must be capable of being operated from above the bulkhead deck. Where, in addition to the main bilge pumping system, an emergency bilge pumping system is provided then it is to be independent of the main system and so arranged that a pump is capable of operating on any compartment under any flooding condition envisaged by the Convention. In this case only the valves necessary for the operation of the emergency system need be capable of being operated from above the bulkhead deck.

All cocks and valves which can be operated from above the bulkhead deck must have their controls at their place of operation clearly marked and be provided with means to indicate whether they are open or closed.

At surveys the following should be verified:-

(i) Confirm operation of pumps and suction from main source of power.
(ii) Confirm operation of nominated pump supplied from emergency source of power.

NOTES

(iii) Check operation of all bulkhead and other remotely controlled valves from above the bulkhead deck.

P016 Bulkhead Valves on other Systems

In order to maintain the integrity of watertight bulkheads it is necessary to fit bulkhead valves on any piping system that would otherwise lead to progressive flooding should that system, through damage, be laid open to the sea. Sewage and dirty water systems often require to be fitted with these valves when sanitary spaces are located in various watertight compartments below the bulkhead deck. These valves are to be capable of remote control from above the bulkhead deck and indicators are to be fitted to show whether the valve is open or closed.

P017 Watertight Bulkhead Doors

It is obviously necessary to fit watertight doors where access is provided through watertight bulkheads. Watertight doors are to be kept closed during navigation except when necessarily opened for the working of the ship, in which case they are always to be ready to be immediately closed.

Only one door is allowed in main transverse bulkheads of main and auxiliary propulsion machinery spaces. Where two shaft tunnels are fitted, they are to be cross connected and served by one watertight door only. If there are more than two shaft tunnels an additional watertight door may be fitted.

The most common type of door encountered will be the sliding type which may be either electro-hydraulic or mechanical in operation.

Power-operated sliding doors may have a vertical or horizontal motion. If a door is required to be power-operated from a central control the gearing is to be so arranged that the door can also be operated by power at the door from both sides. The arrangement must be such that the door will close automatically if opened by local control after being closed from the central control and also such that any door can be kept closed by local systems which will prevent the door from being re-opened from the central control. Local control handles for the power gear are to be provided on each side of the bulkhead and so arranged as to enable persons passing through the doorway to hold both handles in the open position without being able to set the closing mechanism in operation accidentally.

Power-operated sliding doors are also to be provided with hand gear workable at the door itself on either side and from an accessible position above the bulkhead deck. This should be an all round crank motion or some other movement providing the same guarantee of safety and be of an approved type. Provision is to be made to give warnings by sound signal that the door is about to close. The signal is to sound until the door is completely closed.

There are to be at least two independent power sources capable of opening and closing all the doors under control, each of them capable of operating all the doors simultaneously. The two power sources are to be controlled from the station on the navigating bridge and provided with all the necessary indicators for checking that each power source is capable of giving the required service.

At surveys the following should be verified:-

(i) Check the mimic panel and confirm that all lights are working.

(ii) Close all doors from the bridge (within 60 seconds) and confirm closures from mimic panel.

(iii) With doors on 'bridge closure', tour the ship passing through each watertight door and confirm automatic closure after opening.

(iv) Confirm local opening and closing of all doors by both power and manual operation and check local sound warning signals operate when doors are closed.

(v) Close all doors individually from their remote control stations above the bulkhead deck.

PART III
CONVENTION RADIO REQUIREMENTS

The radio installation onboard merchant ships is provided for two purposes; communications for safety of life at sea, and service and commercial communications. During a radio survey the installation is to be examined for correct provision and operation in accordance with the requirements of the SOLAS Convention applicable to the vessel.

The following guidance is given with respect to SOLAS 74 Chapter IV and the 1981 and 1983 Amendments thereto.

Regulation 5 of Chapter IV allows Contracting Governments to exempt any vessel under their jurisdiction from any requirement of the Convention. Increasingly as the radio communications of the present safety system, based on 500 kHz radiotelegraphy and 2182 kHz radiotelephony for ships greater than and less than 1600 gross registred tons respectively, evolves toward the Future Global Maritime Distress and Safety System with mandatory equipment determined by an area of operations concept, exemptions and so-called equivalency arrangements will be met. It is important that the documentary evidence for such exemptions is available on board and is referred to on the Radio Certificate issued.

The majority of equipment and ancillary items comprising a radio installation covered by the carriage requirements of the Convention are required to conform to a minimum performance standard. Most Administrations subscribe to these standards but some require more stringent or peculiarly national specifications to be complied with. An Administration may accept a statement from the manufacturer that equipment conforms to the relevant IMO performance standard or, as is more usual in Europe, impose type testing where an actual equipment is subjected to tests to ensure conformity with the appropriate specification. Those manufactured and fitted subsequently are assumed to comply. All equipment should be marked to indicate its type approval status, but many are not.

The text of Chapter IV contains some basic performance requirements and others are referenced to various Assembly Resolutions. In general, the more detailed technical specifications are published under the aegis of, for example, the CEPT (European Posts and Telegraphs Conference) in Europe and the FCC (Federal Communications Commission) in the USA.

Chapter IV (Radiotelegraphy and Radiotelephony) and Chapter V (Safety of Navigation) are interrelated, with direction finders and VHFs being cross-referenced, as is, to a lesser extent, Chapter III of the 1983 Amendments which requires the provision of EPIRBS and two-way radio telephones. Radar installations and ARPAs are also described in Chapter V, and are reported in Lloyd's Register's Radio Report 2096 and Report SE1.

IMO performance standards are published under a variety of Assembly Resolutions some of which have been collected together in an extract under the title "Performance Standards for Navigational Equipment 1982", and others referenced in Chapter V Regulation 12 (r).

The use of the radio station is governed by the International Telecommunication Union with regard to licences, accounting, signalling codes and message formats (eg distress messages). Every radio station and every operator thereof requires a licence or certificate. The ship licence is the responsibility of the shipowner and is obtained from the Administration of the flag state. For the SOLAS Convention, operator requirements are defined by the Radio Regulations published in the "Manual for use by the Maritime Mobile and Maritime Mobile-Satellite Services" under RR55. The requirement for the documents to be carried onboard is specified in AP11.

Radiotelegraphy Stations
General Requirements, Regulation 9.

During construction of the ship the size, layout and position

of the radio room and antennas should have been approved by the appropriate flag state authorities. Particular attention should have been given to ensuring a minimum level of acoustic and electrical noise. [see paragraphs a, b, c and e]. Communications between radio room and bridge can be direct (hatch or open door), or via voicepipe or dedicated telephone [d].

The clock required should be marked with the radiotelegraphy silence periods, from 15 to 18 and 45 to 48 minutes past each hour, during which time all vessels should cease transmission on the distress frequency and maintain a careful listening watch for distress signals. The clock may also be marked with the radiotelephony silence periods of 00 to 03 and 30 to 33 minutes past the hour [f].

The radio room lighting should be adequate to give proper illumination of the equipment and operating position. For emergency use, independent lighting is required, generally a 24v 25 watt lamp capable of being switched from the entrance to the radio room and at the operating position, and powered from the radio station reserve supply [g]. For servicing, a flashlight or lead-lamp should be provided [h].

Spare parts and test equipment are required to enable the radio station to remain operational while the vessel is at sea. Standards of maintenance and national regulations, if any, vary widely. In general, a comprehensive electrical multimeter, appropriate tools and basic spares such as fuses and lamps should be available. Hopefully an oscilloscope and frequency counter may be onboard, together with electronic components and spare modules for the actual equipment fitted.

Communications Equipment, Regulation 10.

The constituent parts of the radiotelegraphy station are described in this regulation and some technical parameters defined. A main and a reserve installation are required, together with appropriate power supplies, and a main and reserve antenna (aerial).

The Convention requires a minimum range of 150 miles for the main transmitter and 100 miles for the reserve. The only reliable method of verification is to measure the field strength at the desired range from the actual radio transmitter on the ship. In practice an empirical method is used by equating the range required to the product of the transmitter antenna current and maximum height of the antenna above the vessel's deepest load waterline.

Two such tables are given; one for wire antennas (generally of the "T" or "inverted – L" type) and the other for self-supporting cage, mast or rod antennas [g-1]. It should be noted that a higher figure is required in the latter case.

	Minimum normal range in miles	
	Main Transmitter	Reserve Transmitter
All passenger ships and cargo ships of 1 600 grt and upwards	150	100
Cargo ships below 1 600 grt (voluntary radiotelegraphy installations).	100	75

Table 4

Normal range in miles	Metre-amperes	
	Wire antennas	Self-Supporting antennas
150	76	150
100	45	85
75	34	55

Table 5

In most vessels main and reserve transmitting antennas are rigged complete with safety loops in order to provide protection against possible movement of the masts or supports breaking the antenna or halyard. Antennas should be examined for proper rigging and maintenance, e.g. cleanliness of insulators and lack of kinks in the wire, and integrity of halyards. Some of the self-supporting types can be lowered mechanically or hydraulically to be cleaned and checked.

If only one antenna is rigged then a suitable spare antenna is needed and should be ready for immediate installation. Alternatively an electrically equivalent antenna, probably wire, may be provided. Some Administrations require a spare antenna in all cases. Additionally, sufficient antenna wire and insulators, thimbles and shackles should be carried to enable a temporary antenna to be rigged if necessary.

Both main and reserve transmitters are required to transmit on the distress frequency of 500 kHz and at least two other medium frequencies (MF) from the six available between 410 and 512 kHz. Both should function when connected to either main or reserve antenna. Ideally a sketch of the antennas should be available in the radio room to enable the metre-ampere requirement to be calculated.

Within the radiotelegraphy installation means are required for transmission and reception on the radiotelephony distress frequency of 2182 kHz [g-2]. This will generally be found within the main transmitter, complete with an automatic device for generating the radiotelephone alarm signal (ASGD), but may be part of the reserve transmitter, or a dedicated radiotelephony equipment.

The high frequency (HF) facilities of the transmitter, if provided, will generally be checked simply for appropriate output. All frequencies, both MF and HF, should be measured annually to confirm accuracy and stability.

Any radio transmission from the ship should be under the supervision of the radio officer unless the Radio Surveyor holds an operating certificate recognised by the relevant administration. Due care should be taken to keep test signalling to a minimum, to comply with local national regulations regarding transmitting in port and to abide by the ITU procedures. Use of the MF artificial antenna may be helpful [s].

The main and reserve receivers are required to receive signals on 500 kHz and one or both on 2182 kHz, with the main receiver additionally covering all LF, MF and HF marine frequencies for the reception of time signals, navigational warnings, traffic lists and so on. Apart from checking that both equipments function on their appropriate power supplies, the best general test of their serviceability is to monitor a variety of signals, taking special note of the effectiveness of all receiving antennas able to be connected. Electrical noise interference can be a problem especially when alongside and cargo working, and a careful analysis should be made.

The main source of electrical energy should be available from the engine room at all times and switched through the emergency board to enable operation from the emergency generator when necessary. Future requirements under Chapter II-I Regulation 43 of the Convention require provision of an emergency supply to the main radio installation of Chapter IV on both radiotelegraphy and radiotelephony ships of 500 GT and upwards for a period of 18 hours, and also to certain navigational equipment under Chapter V Regulation 12 [A515 (XIII)] [j].

The reserve source of energy will almost always consist of a bank of accumulator batteries of lead acid or nickel-alkaline type with a nominal voltage of 24 v. These must be maintained so that they are capable of supplying the reserve installation for at least six hours [k, l, m, n, o and p]. The battery locker or space should be adequately ventilated and the batteries effectively secured. They should be tested by appropriate means (specific gravity measurement for lead-acid types, terminal voltage for nickel-alkaline) and note made of their serviceability. A discharge test on each cell, whereby a heavy current is drawn and the cell voltage examined over a few seconds, is useful if the

battery condition is suspect. A cell in good order should sustain a consistent terminal voltage over the duration of the test. The battery log should also be examined for evidence of regular charging and maintenances by the crew.

Measurement can be made of the discharge current and a check made that the capacity of the batteries fitted is sufficient. Charging arrangements should also be monitored. As a general rule the batteries should be able to be fully charged from a discharged state within 16 hours.

An automatic radiotelegraph alarm signal keying device (autokey or AKD) is required, capable of keying both main and reserve transmitters. The alarm signal consists of twelve four-second dashes with one second spaces. A check should be made on the timing of this, usually by monitoring the indicator provided, and a brief test made of the keying circuits to each transmitter [r]. Some administrations require additional signals, generally in the format SOS three times plus ship's callsign x 3. These facilities should be checked, particularly at change of flag surveys, to ensure that the vessel's new identity is transmitted in the event of an emergency.

Autoalarm, Regulation 11.

This equipment is to be in use at all times when an aural watch is not being maintained. Signals should be monitored and compared with those from the main receiver on 500 kHz for similar strength and clarity.

The timing tolerances may be checked by keying the test oscillator provided, either manually or via the autokey. An alarm should be given by the end of the fourth dash received and the bells or other warning devices should sound in the radio room, on the bridge and in the radio officer's cabin. The equipment failure alarm circuits should also be checked by interrupting the power supply when, after a short delay, the bells should sound.

Radio Direction Finder, Regulation 12.

The direction-finder is required by Regulation 12 of Chapter V and its technical characteristics are defined in this regulation. It is usually situated on the bridge. Its function is twofold; to ascertain the position of the ship by taking bearings from two or more known radio beacons (for example, a lighthouse or aero beacon), and also to enable the ship to determine the bearing of a vessel in distress. The apparatus should thus receive signals in the maritime beacon band of 285–315 kHz and in the MF telegraphy band of 410–512 kHz [12(a)].

To allow for the fixed errors between the visual (actual) and radio (apparent) bearings, a calibration curve must be provided which shows the correction to be applied. This is achieved by swinging the ship off a suitable transmitting site, and noting visual and radio bearings every 5 degrees through 360 degrees. Alternatively a boat with a suitable transmitter may slowly circle the ship. From the resultant measurements a calibration curve can be produced.

Check bearings are required to be taken in each quadrant at least once a year (visual and radio) and be compared with the calibration curve. They should be consistent. If, however, significant differences are noted, then a new curve should be prepared by recalibration [a(vii)].

Many direction-finders additionally have facilities for receiving signals in the 2 MHz band and sometimes in the HF bands. The requirement for "homing" on 2182 kHz is defined in Chapter V Regulation 12 [q]. In practice, the technical difficulties of achieving consistent and meaningful bearing measurements at this frequency preclude anything other than approximations being made as to whether the signals emanate from one side of the bow or the other. If the direction-finder has 2182 kHz coverage, therefore, the homing requirement can be assumed to be met [b].

Radiotelephony Stations

All Convention radiotelephony ships over 300 GT, and all radiotelegraphy ships, are required to keep a continuous watch on the radiotelephony distress frequency of 2182 kHz by any appropriate means. These are, generally, provided by a watch receiver capable of being muted, that is, in the absence of the reception of a two-tone alarm signal, there is no audio output.

For all radiotelephony ships a radiotelephony operator is required, who should have a certificate issued by an appropriate national administration to satisfy the ITU regulations; on ships over 500 GT two operators are necessary. These operators are invariably deck offers but may be other members of the crew. Alternatively an exclusive operator, holding a radiotelephony or radiotelegraphy certificate, may be provided.

General Requirements, Regulation 15.

These are less comprehensive than those for a radiotelegraphy station in Regulation 9 but have much in common. Means are required for indicating the charge condition of the source of energy, generally a bank of batteries of 24 volts, and, although not very appropriate technically, a voltmeter is generally accepted [e].

Since the radiotelephony operators are not dedicated radio communicators, there is a requirement for a "card of instructions" giving concise and unambiguous directions to facilitate operation of the radiotelephony equipment in an emergency. This card should be supplied by the equipment manufacturer and be written in English or an appropriate language. It may also include the international phonetic alphabet and a summary of distress, urgency and safety signalling.

Communications Equipment, Regulation 16.

A transmitter and receiver are required, together with the necessary sources of electrical power, and an antenna.

The Convention specifies a range of 150 miles for all radiotelephony stations. Unlike radiotelegraphy ships, no practical guidelines are given, other than a nominal power output of 60 watts peak envelope power, and no criteria are given for the 27% antenna efficiency assumed [c(i)]. In practice, therefore, an attempt should be made to confirm that the actual output is similar to that noted on initial installation. Communications should be established between the ship and a convenient coast radio station on 2182 kHz to check signal strength and clarity of transmission.

One antenna is required since there is only one radiotelephony equipment, although provided with a main and reserve power supply. It should be rigged in a seaman-like manner and should have safety loops or other means to protect against parting of the antenna or halyard if its supports are liable to whipping. There should be adequate clearance from all possible obstructions. The antenna should be as high as is practicable. A spare antenna, which may consist of, or include, a rod or whip, complete with insulators and shackles as appropriate, should be available. If not, then sufficient antenna wire and hardware to enable an alternative antenna to be fabricated and rigged, must be provided [m].

The source of energy for the radiotelephony apparatus is defined as main and reserve, and various arrangements are possible. A typical installation will comprise a bank of batteries which is float charged. The batteries are then constantly charged and should be continually capable of supplying energy to the radiotelephony equipment under normal conditions, and for the minimum six hours required should the main source fail. Alternatively, the transmitter and receiver may have a dual mains and battery power supply, functioning on the former in normal circumstances, but capable of being switched immediately to the battery supply when necessary. Yet another system provides two banks of batteries, one in use, the other being charged. Occasionally a main source of energy only may be found, but this must then be situated in the upper part of the ship. Care should be taken to confirm the effectiveness and serviceability of the installation whatever its form [i].

The bank of batteries usually provided must have an

adequate capacity. A check can be made of the discharge and charge currents to ascertain the adequacy of the power source. Typically a minimum capacity of 150 ampere-hours will be encountered. The constraints placed on the equipment permitted to be connected to the reserve source of energy as defined in [j] and [k] should be noted.

VHF Installations, Regulation 17

One VHF radiotelephone is required, complete with an efficient antenna and a power supply which, on all passenger ships and cargo ships over 500 GT, must be situated in the upper part of the ship and have an endurance of at least six hours. However, most VHFs will be powered from a main source of power (standard ship's mains supply via the emergency switchboard) with either manual or automatic changeover to a 24v supply, generally from the radio batteries. If this is the arrangement, then the capacity of the radio batteries has to be adequate. No figures are specified but an extra 15 ampere-hours should suffice [a, b and c]. If the emergency generator is situated in the upper part of the vessel and can supply the VHF, this requirement is also satisfied since the generator has to function for a minimum of 18 hours. [Chapter II-I Regulation 43.2.4].

Control of the VHF is required to be available on the bridge, on a priority basis if there are multiple control units [f]. If more than one VHF equipment is fitted only one need comply with this regulation.

There are no specific international requirements for frequencies or channels to be fitted, apart from Channel 16, other than that they conform to the ITU Radio Regulations. Earlier equipment may have limited numbers but the majority of contemporary VHF equipment covers all international simplex channels for inter-ship and ship-shore working plus duplex channels for public correspondence.

Motor Lifeboat Fixed Radiotelegraphy Installation, Regulation 13

This is required on certain passenger vessels under the conditions specified in Regulation 6.2.2 of Chapter III.

The installation must transmit and receive radiotelegraphy signals on 500 kHz and also on 8364 kHz (the frequency defined by the ITU Radio Regulations for use by survival craft in the HF bands). It requires an automatic keying device for transmitting the radiotelegraphy alarm signal and the distress signal (SOS x 3). Power should be derived from a bank of batteries, capable of being charged from the lifeboat's engine, and kept in a fully charged state when the vessel is at sea by means of an umbilical power supply [b, d, f and g] from the ship.

An antenna must be provided and, due to the constraints imposed by the small size of a lifeboat, may be of somewhat bizarre form and construction. A range of 25 miles is required for 500 kHz and a guide is given in the metre-ampere form [i]. However, effective testing will be confined to occasions when the lifeboat is afloat and clear of the ship.

Portable Radio Apparatus for Survival Craft, Regulation 14

All ships over 500 GT must be equipped with a portable radio apparatus for use in survival craft. Some Administrations extend this requirement to vessels of 300 GT and upwards.

The equipment should have transmitting and receiving facilities for the radiotelegraphy distress frequency of 500 kHz and also for 8364 kHz to enable HF long distance signalling [See ITU RR38]. It may also have provision for radiotelephony on 2182 kHz on a voluntary basis, or, more unusually, instead of 8364 kHz [c].

An AKD capable of keying the transmitter with the radiotelegraphy alarm and distress signals is required. Facilities for transmitting the call sign of the parent vessel are not required. Additionally, if radiotelephony frequencies are provided, a two-tone ASGD must be included [e].

The whole equipment will be self-contained (including the antenna), is usually powered by a hand-turned generator and should be stowed on or near the bridge. During routine testing the apparatus should be unpacked and assembled, the antenna rigged provisionally, and the earth lead connected to the ship's structure. Contact should be established with a local radio station to check the equipment's facilities and to engender a feeling of confidence in its operation. On rare occasions it may be possible to rig the equipment on a lifeboat and attempt communications under realistic conditions.

On conclusion of tests, it is essential to re-pack the apparatus carefully, making sure that all accessories are available and the case is watertight and stowed so that it is ready for immediate use should an emergency arise.

Emergency Position Indicating Radio Beacons, Regulation 14/1/2

These are required in order to provide transmissions to enable location of the survival craft [a].

To this end EPIRBs should transmit on the aeronautical watch frequencies of 121.5 and 243 MHz and comply with minimum performance standards [b and c].

Discussions continue at IMO with respect to the future alerting and locating functions of EPIRBs and the latter role may be overtaken by 9 GHz radar transponders. Alternative or complementary alerting systems using EPIRBs will use the 406 MHz band through the Cospas-Sarsat System adopted by IMO for the (Future) Global Maritime Distress and Safety System.

Two-way Radiotelephone Apparatus, Regulation 14–3

A minimum of three portable equipments are required. They may use frequencies in the VHF maritime band (156–163 MHz) or UHF band (470 MHz). An endurance of four hours is required with a duty cycle of one period transmitting to nine periods receiving using dry or rechargeable cells. Checks should be made on the serviceability of these radiotelephones, of the maintenance procedures adopted onboard to ensure a constant state of readiness, and on the sort of communications range achieved within and around the ship.

EPIRBs and two-way radiotelephones as above are required *now* on "new ships" and by 1 July 1991 on "existing ships" the keels of which were laid before 1 July 1986.

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APPENDIX A
SURVEY AND TEST PROCEDURES FOR THE FIRE MAIN

Initial Inspections

1. Check hydrant positions and hose positions and that the nozzles are stowed with the hoses together with any tools necessary for their operation.
   These should be in accordance with the approved plan, but as such plans are often diagrammatic, the surveyor should verify that two jets of water may be directed on any part of the ship including the cargo holds when empty. Check that combined jet and spray nozzles are readily adjustable.
2. Check that no systems are connected to the fire main other than those specially catered for and permitted by the approved plans.
3. Check drain valves and isolating valves as shown on the approved plans.
4. Check that all manifold valves are readily accessible and clearly marked. They should be sited reasonably near to the pumps.
5. Check the length and diameter of the hoses.
6. Check the marking of the hose boxes.
7. Run the fire pumps simultaneously, discharging through the fire main.
8. Test that an adequate jet can be produced simultaneously from the two highest hydrants using each pump singly, or from the two hydrants most remote from the pump if in the surveyor's opinion that would be more onerous.
9. Run the pumps with the fire main and all systems connected to it operating simultaneously and check that the jets required by foregoing item (1) can be produced.
10. Ensure that the relief valves are set to operate properly, and discharge to a suitable location.
11. Check the starting of the emergency fire pump and test it with the ship in the light condition discharging to all parts of the fire main outside the compartment containing the main fire pumps. Check that the fuel capacity is sufficient.
12. Check the international shore connections.

Periodic Inspections

1. Run each fire pump and check that the pumping capacity is adequate. Check the starting of the emergency fire pump.
2. Examine all hoses. They should be ranged, including those which look new. Pay particular attention to the attachment of the hoses to the couplings. Run water through each hose at pressure and check for leaks.
3. Ensure that water is flowing and that the couplings are undamaged.
4. Examine the fire main, paying particular attention to the joints. Operate the isolating valves.
5. Check the nozzles and the international shore connections and any tools required for connecting the hose.
6. Check the marking of the hose boxes.

APPENDIX B
SURVEY AND TEST PROCEDURES FOR PORTABLE FIRE EXTINGUISHERS

1. All portable fire extinguishers should be examined at each Renewal, Intermediate and Annual Safety Equipment Survey. If there is any sign of corrosion, leakage or damage the extinguisher concerned should be tested by discharging, cleaning, repairing as necessary, hydraulically testing and refilling. The instructions for use should be clearly marked on the wall of the canister and each type painted in accordance with Table 7.
2. Water (soda acid) with loose stopper acid bottle, water (stored pressure) and chemical foam extinguishers should be tested by discharging at least once every two years and the charge renewed.
   Water (soda acid) with loose stopper acid bottle, water (gas cartridge), powder (gas cartridge) powder (stored pressure) field refillable type should be tested by discharging at least once every five years.
   After discharge the extinguisher should be examined for damage and corrosion and if such is found it should be cleaned and repaired as necessary and then tested to a hydraulic pressure of 1.5 times the working pressure or 21 bars whichever is the greater for dry powder extinguishers and the remainder to 24 bars before recharging.
   Carbon dioxide extinguishers should be checked by weight and if a loss of more than 10 per cent of the contents, or more than the percentage recommended by the manufacturers if less than 10 per cent, is detected the extinguisher should be tested by discharging and then refilled.
3. If a cylinder is corroded or damaged, but in the opinion of the surveyor, based on a visual examination, not serious enough to warrant its rejection it should be subjected to a hydraulic test before recharging.
   Some flag administrations require that all cyclinders should be subjected to a hydraulic pressure test after ten years and subsequently after a further ten years and thereafter at intervals not exceeding five years.
4. Halon and dry powder (stored pressure) factory sealed type extinguishers should be tested by discharging and hydraulic testing after ten years and subsequently after a further ten years and thereafter at intervals not exceeding five years.
5. Water, chemical foam and dry powder extinguishers should be tested hydraulically to at least 21 bars once every four years.

Space	Suitable type of extinguisher	Fire Type
Accommodation space	Water, dry powder	A
Galley	Foam, dry powder, halon, CO_2	B
Radio room	Dry powder, halon, CO_2	C
Machinery space	Dry powder, foam	B
Boiler space	Foam	B
Electrical equipment	Dry powder, halon, CO_2	C

The capacity of portable extinguishers should be between 9 and 13.5 litres or equivalent.

Table 6 Guide to the location of portable fire extinguishers

Type	Type of fire for which suited	Suitability for fires involving electrical equipment	Capacity for ship use	Colour coding
Water	A	No	9 litres (2 gallons)	Signal Red
Foam	B	No	9 litres (2 gallons)	Pale Cream
Dry powder	ABC	Yes	3 kg (7 lbs)	French Blue
BCF (Halon 1211)	BC	Yes	1.5 kg (3 lbs)	Emerald Green
(Halon 1301)	BC	Yes	1.5 kg (3 lbs)	Emerald Green
CO_2	BC	Yes	2.3 kg (5 lbs)	Black

Table 7 Portable fire extinguishers

The following table may be used as a guide for assessing the suitability of various types of extinguishers. The capacities quoted are in U.S. gallons or pounds which equate to 3.785 litres and .45 kgs respectively.

Fire Classification	Portable/ Semi-portable	Water U.S. gallons	Foam U.S. gallons	CO_2 lbs	Dry Powder lbs
A	P	$2\frac{1}{2}$	2	4	2
B	P		1	4	2
B	P		2	15	10
B	SP		12	35	20
B	SP		20	50	30
B	SP		40	100	50
C	P			4	2
C	P			15	10

Table 8

APPENDIX C
SURVEY AND TEST PROCEDURES FOR BREATHING APPARATUS

1. Air Hose Type
   1.1 Examine the face mask for its general condition paying particular attention to the securing straps and the connection of the air hose.
   1.2 Examine the condition of the air hose and the foot pump bellows.
   1.3 Test the assembled set when worn by a man, checking that the air delivery to the face mask is adequate.
2. Self-Contained Breathing Apparatus (figs 17 and 18).
   2.1 Examine the face mask for its general condition and particularly the straps for securing it to the head of the wearer and the condition of the visor.
   2.2 Examine the condition of the tube from the reducing valve to the face mask.
   2.3 Examine the condition of the air cylinders.
   2.4 Check the cylinder is full by turning off the demand valve and slowly opening the cylinder valve then verify the pressure gauge reading against the pressure stated on the cylinder.
   2.5 Recharge the cylinders as necessary.
   2.6 Check for leaks in the apparatus by slowly opening the cylinder valve to obtain a gauge reading. Close the cylinder valve. The gauge reading should not fall by more than 10 bar/minute.
   2.7 Check the whistle warning setting by gradually reducing the pressure in the system by slowly opening the demand valve. The whistle should blow at the stipulated low pressure reading in the manufacturers handbook.
   2.8 Get a man to wear the set and, with the face mask hanging free, gently open the by-pass valve or demand valve and ensure that air is discharged into the face mask; this should be clearly audible. Shut the valve.
   2.9 With the man wearing the face mask, restrict the air supply by closing the cylinder valve, and the mask should collapse on the face after one or two breaths. Open the cylinder valve immediately.
   2.10 All the above tests should be carried out under the direction of a responsible ship's officer who is to see that the set is properly cleaned, disinfected, dried and stowed on completion.
   2.11 The method of effecting the above mentioned tests will vary according to the design of the apparatus. Reference should be made to the manufacturer's instruction manual.

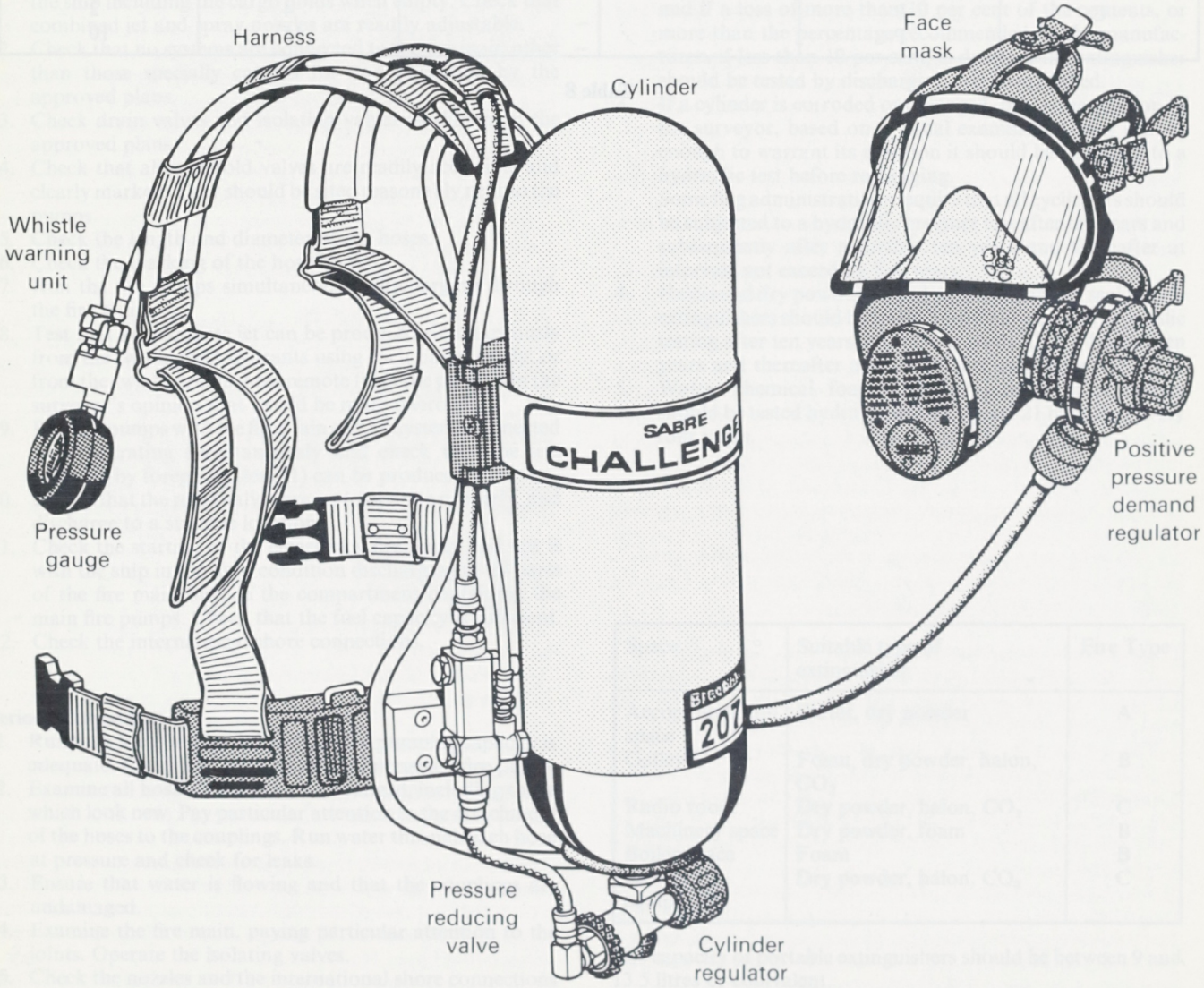


Fig 17

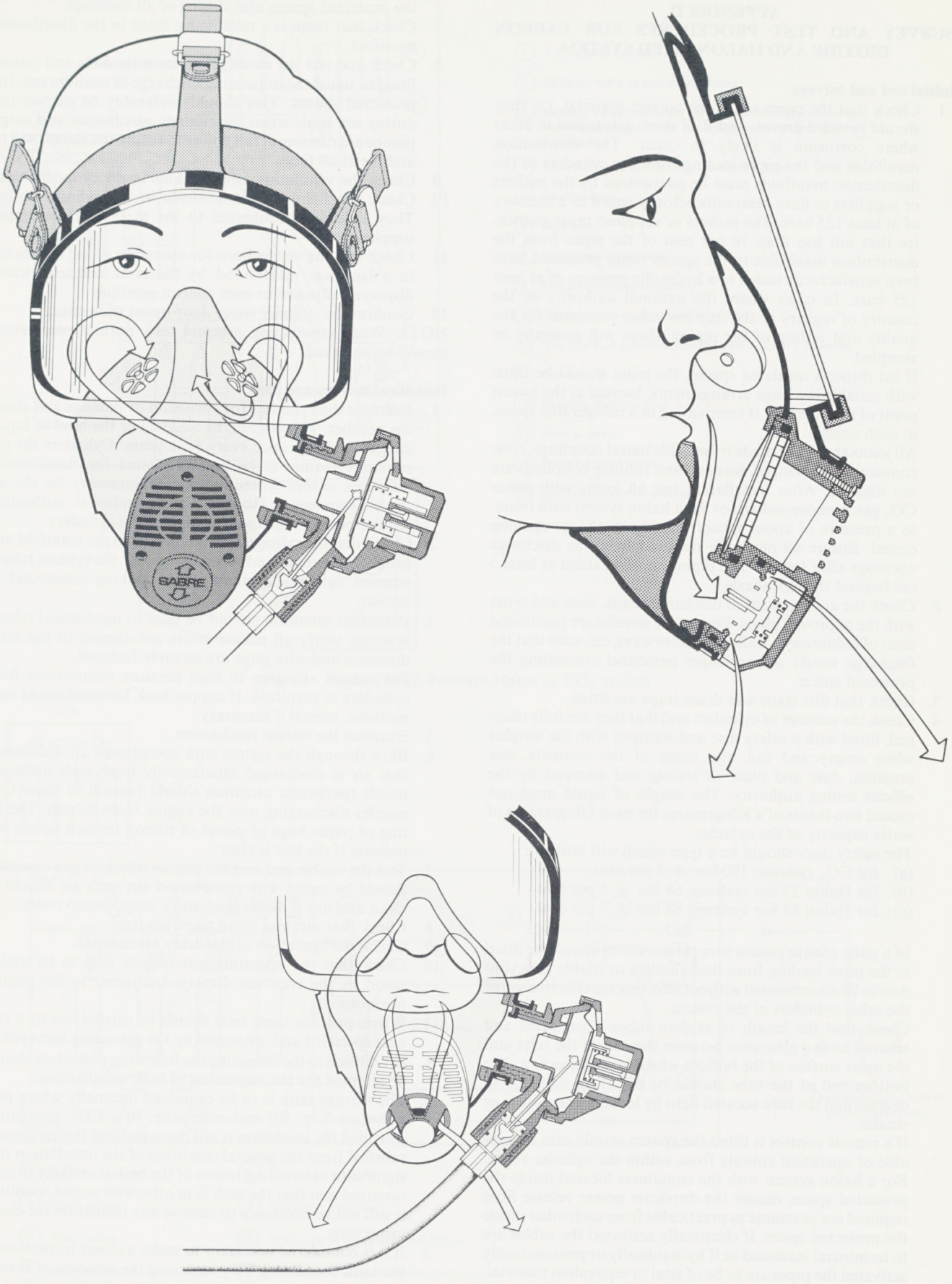


Fig 18

APPENDIX D
SURVEY AND TEST PROCEDURES FOR CARBON DIOXIDE AND HALON FIXED SYSTEM

Initial test and surveys

1. Check that the pipes are of the correct material, i.e. they should be solid drawn, and if of steel, galvanised in areas where corrosion is likely to occur. The distribution manifolds and the pipes leading from the cylinders to the distribution manifolds must be guaranteed by the makers or suppliers to have been satisfactorily tested to a pressure of at least 125 bars. The makers or suppliers must guarantee that not less than 10 per cent of the pipes from the distribution manifolds to the spaces being protected have been satisfactorily tested to a hydraulic pressure of at least 125 bars. In cases where the national authority of the country of registry of the ship has other standards for the quality and testing of the piping, these will generally be accepted.
   If led through insulated spaces, the pipes should be fitted with suitable drainage arrangements, located at the lowest point of the pipe and, if terminating in a refrigerated space, at each nozzle.
   All joints should be made by suitable barrel couplings, cone connections or flanges. Screwed and running couplings are not allowed. After installation test all joints with either CO_2 gas, compressed air, or for a halon system with freon, to a pressure of about 6 bars with the discharge opening closed. Ensure all plugs are removed from the discharge openings after testing. The piping should extend at least 5 cm beyond the last nozzle.
2. Check the arrangement of discharge heads, sizes and types with the approved plans. Ensure the nozzles are positioned clear of ladderways, walkways, doorways, etc. such that the discharge would not endanger personnel evacuating the protected space.
3. Check that dirt traps and drain traps are fitted.
4. Check the number of cylinders and that they are fully charged, fitted with a safety disc and stamped with the weights when empty and full, the name of the contents, test pressure, date and place of testing and stamped by the official testing authority. The weight of liquid must not exceed two thirds of a kilogramme for each kilogramme of water capacity of the cylinder.
   The safety discs should be a type which will burst at:
   (a) for CO_2 systems; 190 bar ± 5 per cent
   (b) for Halon 25 bar systems; 68 bar ± 5 per cent
   (c) for Halon 42 bar systems; 88 bar ± 5 per cent

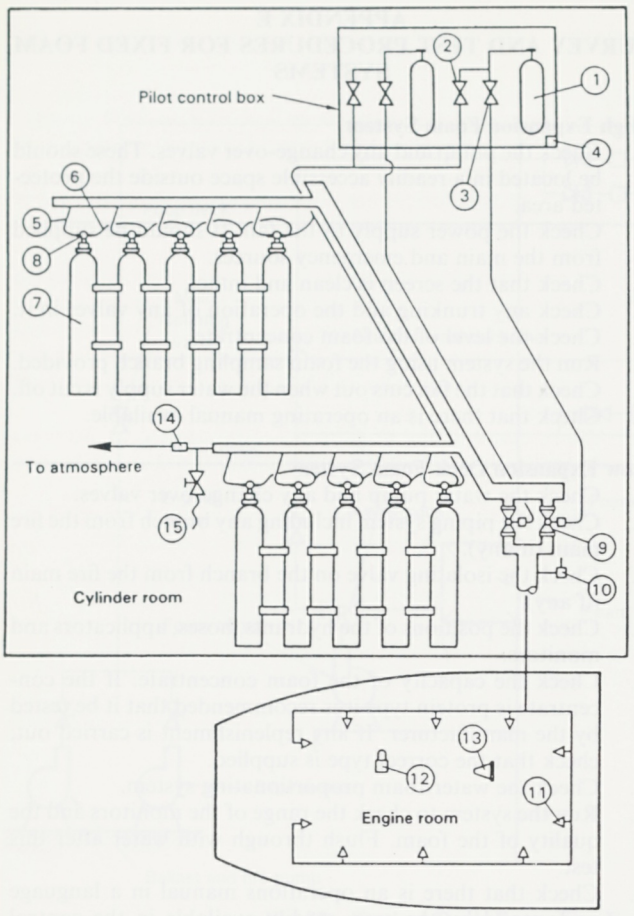
   In a gang release system non-return valves should be fitted in the pipes leading from the cylinders to enable the cylinders to be disconnected without affecting the effective use of the other cylinders of the system.
   Check that the length of syphon tubes when fitted and secured have a clearance between the end of the tube and the inner surface of the bottom which is not excessive. The bottom end of the tube should be cut at an angle of 45 degrees and the tube secured tight by locking compound or similar.
   If a remote control is fitted the system should also be capable of operation entirely from within the cylinder room. For a halon system with the containers located inside the protected space, ensure the duplicate power release lines required are as remote as practicable from each other inside the protected space. If electrically activated the cables are to be mineral insulated or if hydraulically or pneumatically activated the pipes are to be of steel or equivalent material.
5. The remote controls, local controls and automatic release controls, if fitted, should be operated.
6. Check the operation of the gas release delay mechanism and the automatic means to stop ventilating fans serving the protected spaces and closing of all openings.
7. Check that there is a relief valve fitted in the distribution manifold.
8. Check and test the automatic alarms (audible and visual) fitted to signal the impending discharge of medium into the protected spaces. This should preferably be carried out during sea trials when the engines, auxilliaries and cargo pumps are running at full power to ensure the alarms will be audible at all times.
9. Check the ventilating arrangements in the cylinder room.
10. Check the lighting arrangements in the cylinder room. They should be connected to the main and emergency supplies.
11. Check that the instructions for operation of the system are in a language understood by the crew and are clearly displayed adjacent to each control position.
12. Confirm the cylinder room door opens outwards.

NOTE: When conducting pressure tests normal precautions should be observed.

Periodical surveys and tests

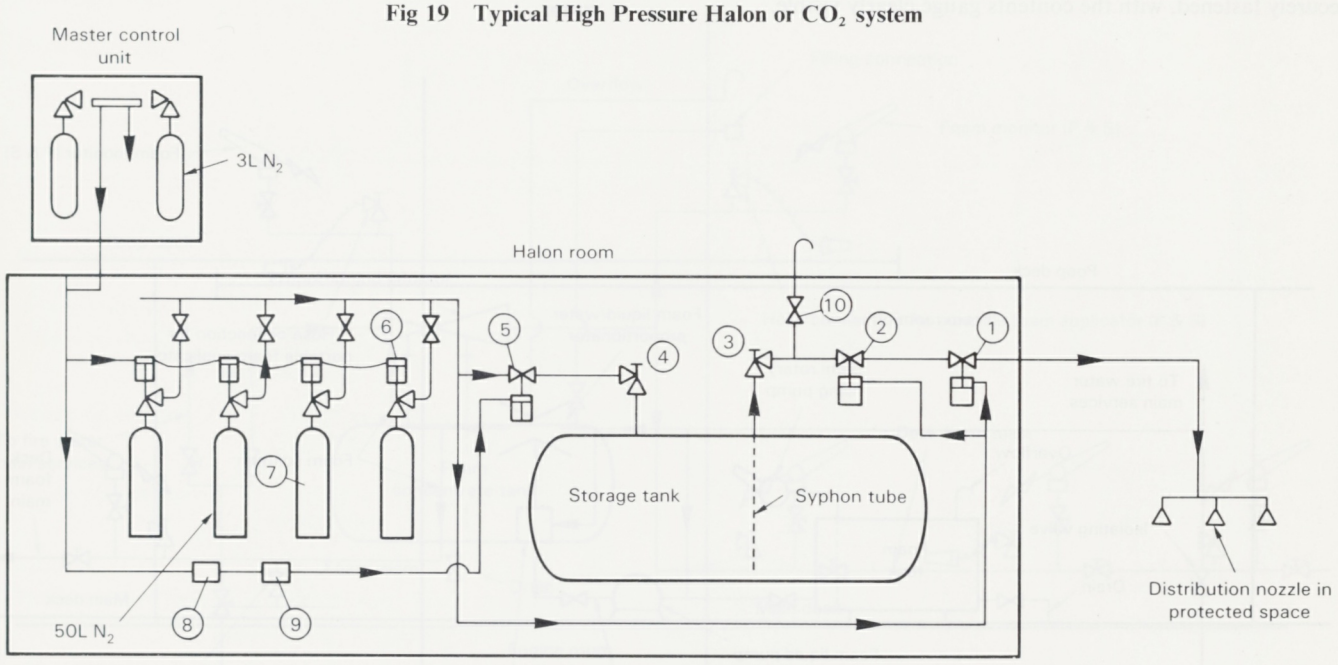
1. Examine the cylinders for corrosion or damage and check the number. They should be weighed or the level of liquid gauged, at least once every four years. Cylinders do not normally require to be pressure tested for classification purposes, except where considered necessary by the attending surveyor. However, some national authorities require periodic hydraulic testing of the cylinders.
2. Check that the cylinders are connected to the manifold and properly mounted and secured and that the syphon tube is screwed tight and secured with a locking compound or similar.
3. Particular attention should be paid to mechanical release systems, verify all release levers are aligned in the same direction and wire grips are securely fastened.
4. Pay special attention to high pressure connections from cylinders to manifold. If copper look for cracking at connections, anneal if necessary.
5. Examine the release mechanism.
6. Blow through the system with compressed air and ensure that air is discharged satisfactorily from each discharge nozzle (particular attention should be paid to those CO_2 nozzles discharging over the engine room bilges). The fitting of paper bags or pieces of ribbon to each nozzle will indicate if the line is clear.
7. Test the visible and audible alarms which, if gas operated, should be tested with compressed air; such air should be clean and dry if discharged into a cargo pump room.
8. Check that dirt and drain traps are free.
9. Check the operation of the delay mechanism.
10. Check that the operating instructions able to be understood by the crew are displayed adjacent to the control positions.
11. Where possible these tests should be carried out by a reliable specialist and witnessed by the attending surveyor.

1. In addition to the foregoing the following procedure should be adopted for the inspection of bulk installations.
2. The storage tank is to be examined internally where possible (see 7, p. 90) and externally. In a CO_2 installation provided the insulation is not damaged and the surveyor is satisfied from the general condition of the installation that significant external corrosion of the tank is unlikely to have occurred and that the tank is in otherwise sound condition it will not be necessary to remove any insulation for closer inspection.
3. If it is considered necessary to make a closer inspection of the tank containing CO_2 requiring the removal of insulation the manufacturers of the storage facility should be consulted before the work is started. If any difficulty is encountered in obtaining advice from the manufacturers the matter should be referred to Headquarters.



1. 2.2 Kg pilot cylinder
2. Selector valve to operate cylinders
3. Selector valve to operate main pressure operated release valve arranged so that it cannot open before valve (2) is operated
4. Door switch to operate alarms in engine room
5. Flexible loop
6. Pilot loop
7. High pressure cylinder
8. Pressure/manual actuator
9. Pressure operated valve with switch
10. Gas operated pressure switch to shut down E.R. vents
11. Nozzle
12. Rotating flashing lamp
13. Horn or siren
14. Pressure relief valve
15. Compressed air connection

Fig 19 Typical High Pressure Halon or CO_2 system



1. Distribution valve
2. Main valve
3. Stop valve
4. Nitrogen stop valve
5. Main stop valve
6. Non-return valve
7. Nitrogen cylinder
8. Main alarm for protected space
9. Ventilation stop for protected space
10. Safety valve

Fig 20 Typical Bulk Halon System

4. The level of liquid in the storage tank is to be checked. A loss of more than 5 per cent by weight of liquid is to be made good.
5. Control instrument and alarms pertinent to the maintenance of the CO_2 storage conditions are to be tested.
6. Storage tank relief valves are to be changed over at least every two years and the lifting pressure of the relief valves tested. Other relief valves in the filling and discharge lines are to be tested at least every four years.
7. Storage tanks should be internally examined at any time when they are empty provided that the interval between internal examinations does not exceed ten years. Tanks are to be thoroughly ventilated before entry. Where an installation has more than one storage tank and not all tanks have been emptied, suitable precautions should be taken to prevent the inadvertent admission of CO_2 or halon into the tanks opened up for examination.
8. Bulk storage tanks should be confirmed completely dry before re-charging with CO_2 in order to avoid internal icing and therefore possible failure of valves etc.
9. In a CO_2 system each unit of the refrigeration installations serving the storage facility is to be examined under working conditions. The capability of each unit to maintain the contents of the storage tanks at the required temperature using main and emergency power supplies is to be verified.
10. Any safety cut-outs are to be tested. Earth continuity arrangements fitted to prevent the build up of static electricity are to be examined.

Reports have been received of locally installed halon cylinders being found empty. Due to vibration, cylinders have turned within their storage straps and thereby have rendered the release mechanism defective and initiated a slow release of the gas into the protected space. In some cases the gas has not been released but the contents gauges have relocated themselves so as to become unreadable. All cylinders should therefore be confirmed securely fastened, with the contents gauge clearly visible.

APPENDIX E
SURVEY AND TEST PROCEDURES FOR FIXED FOAM SYSTEMS

High Expansion Foam System

1. Check the pump and any change-over valves. These should be located in a readily accessible space outside the protected area.
2. Check the power supply to the fan. It should be supplied from the main and emergency sources.
3. Check that the screen is clean and intact.
4. Check any trunking and the operation of any valves in it.
5. Check the level of the foam concentrate.
6. Run the system using the foam sampling branch provided.
7. Check that the fan cuts out when the water supply is cut off.
8. Check that there is an operating manual available.

Low Expansion Deck Foam System

1. Check the water pump and any change-over valves.
2. Check the piping system including any branch from the fire main (if any).
3. Check the isolating valve on the branch from the fire main (if any).
4. Check the positions of the hydrants, hoses, applicators and monitors.
5. Check the capacity of the foam concentrate. If the concentrate is protein type it is recommended that it be tested by the manufacturer. If any replenishment is carried out, check that the correct type is supplied.
6. Check the water/foam proportionating system.
7. Run the system to check the range of the monitors and the quality of the foam. Flush through with water after this test.
8. Check that there is an operations manual in a language understood by the crew readily available in the control room.

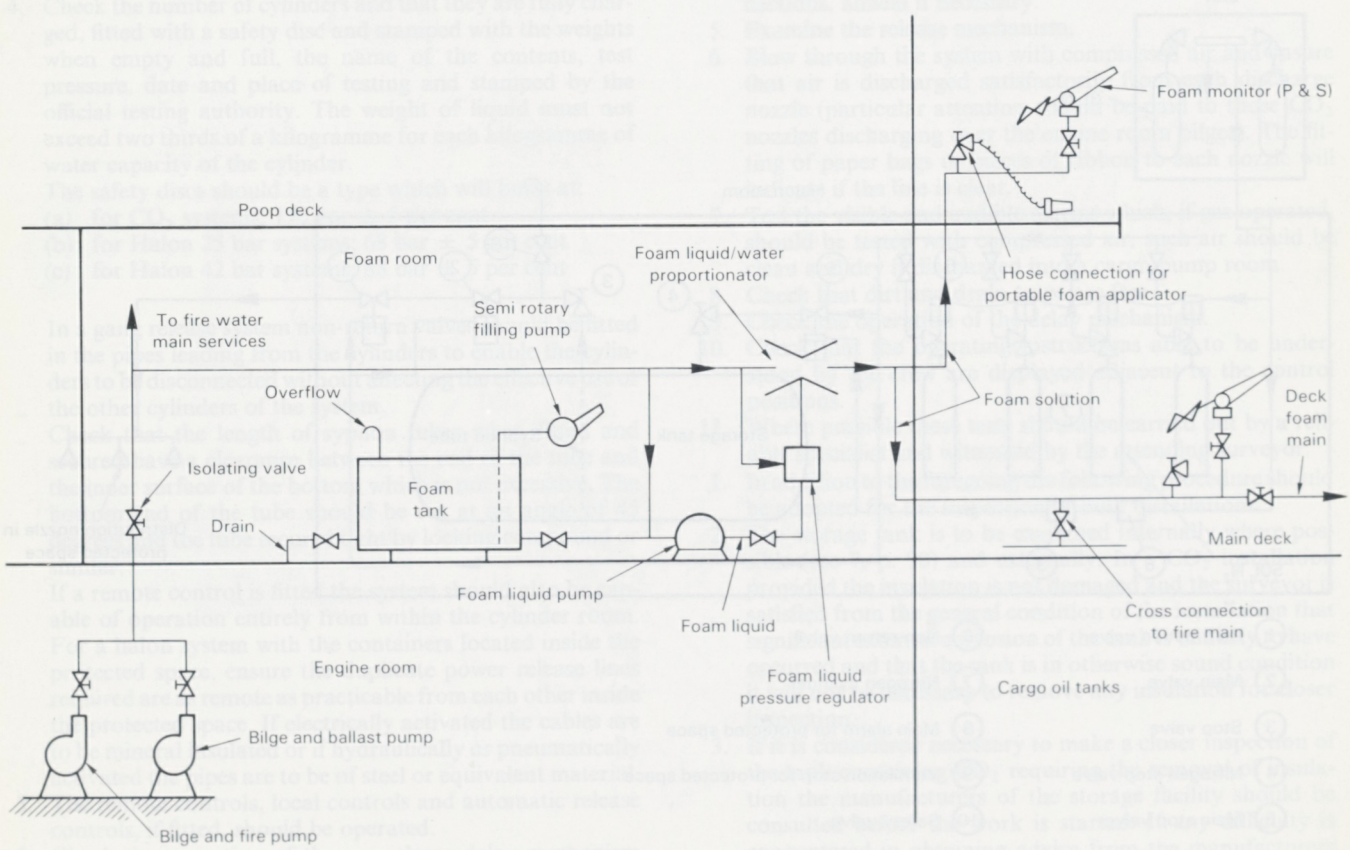


Fig 21 Typical Deck Foam Fire Extinguishing System with Proportionator

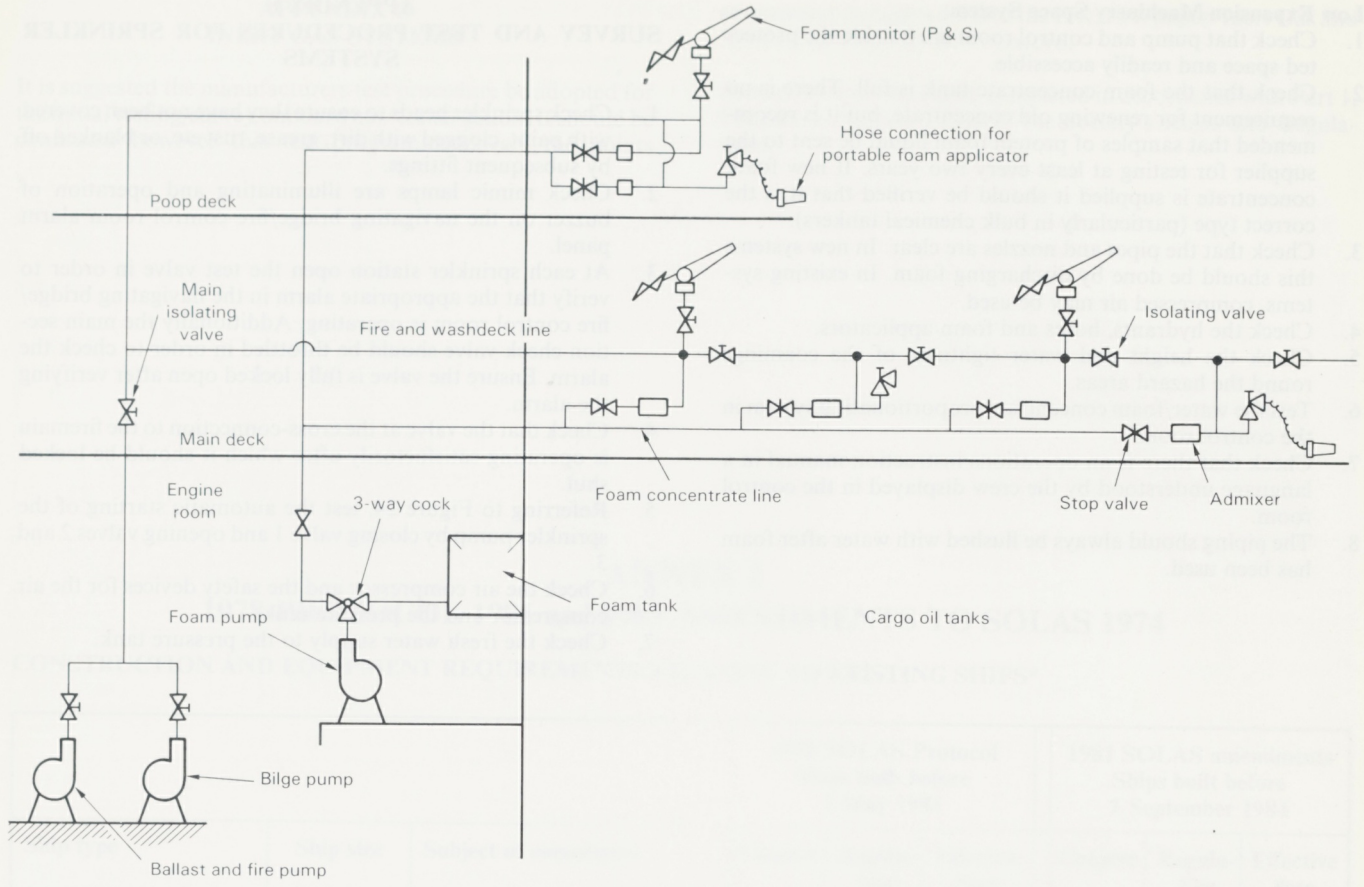


Fig 22 Typical Deck Foam Fire Extinguishing System with Proportioning Eductor

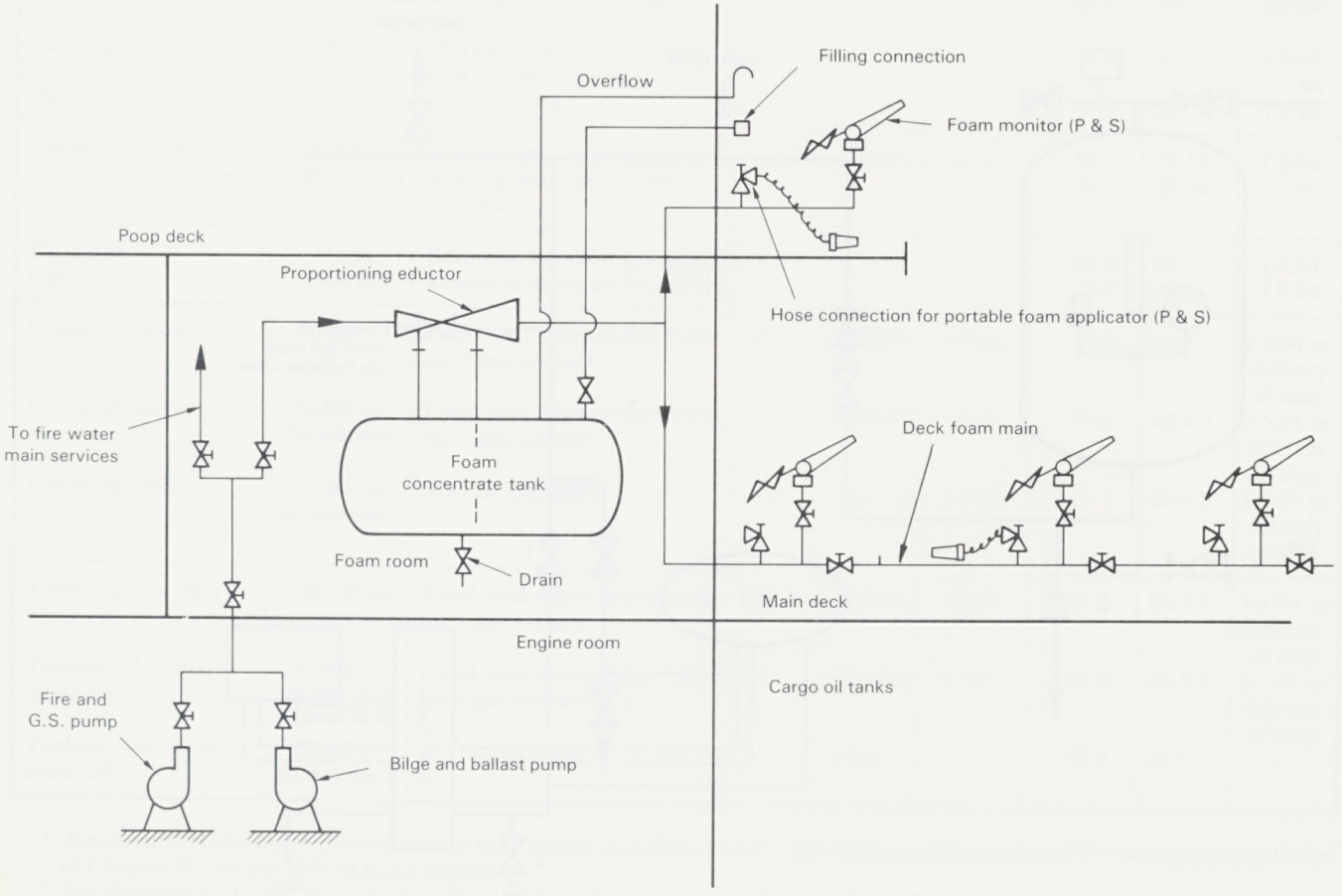


Fig 23 Typical Deck Foam Fire Extinguishing System with Admixer

Low Expansion Machinery Space System

1. Check that pump and control room are outside the protected space and readily accessible.
2. Check that the foam concentrate tank is full. There is no requirement for renewing old concentrate, but it is recommended that samples of protein foam liquid be sent to the supplier for testing at least every two years. If new foam concentrate is supplied it should be verified that it is the correct type (particularly in bulk chemical tankers).
3. Check that the pipes and nozzles are clear. In new systems this should be done by discharging foam. In existing systems, compressed air may be used.
4. Check the hydrants, hoses and foam applicators.
5. Check the height and water tightness of the coamings round the hazard areas.
6. Test the water/foam concentrate proportionating system in the control room.
7. Check that there is an operations instruction manual in a language understood by the crew displayed in the control room.
8. The piping should always be flushed with water after foam has been used.

APPENDIX F
SURVEY AND TEST PROCEDURES FOR SPRINKLER SYSTEMS

1. Check sprinkler heads to ensure they have not been covered with paint, clogged with dirt, grease, rust etc. or blanked off by subsequent fittings.
2. Check mimic lamps are illuminating and operation of buzzer on the navigating bridge/fire control room alarm panel.
3. At each sprinkler station open the test valve in order to verify that the appropriate alarm in the navigating bridge/fire control room is operating. Additionally the main section check valve should be throttled in order to check the alarm. Ensure the valve is fully locked open after verifying the alarm.
4. Check that the valve at the cross-connection to the firemain is operating satisfactorily after which it should be locked shut.
5. Referring to Figure 24, test the automatic starting of the sprinkler pump by closing valve 1 and opening valves 2 and 3.
6. Check the air compressor and the safety devices for the air compressor and the pressure tank.
7. Check the fresh water supply to the pressure tank.

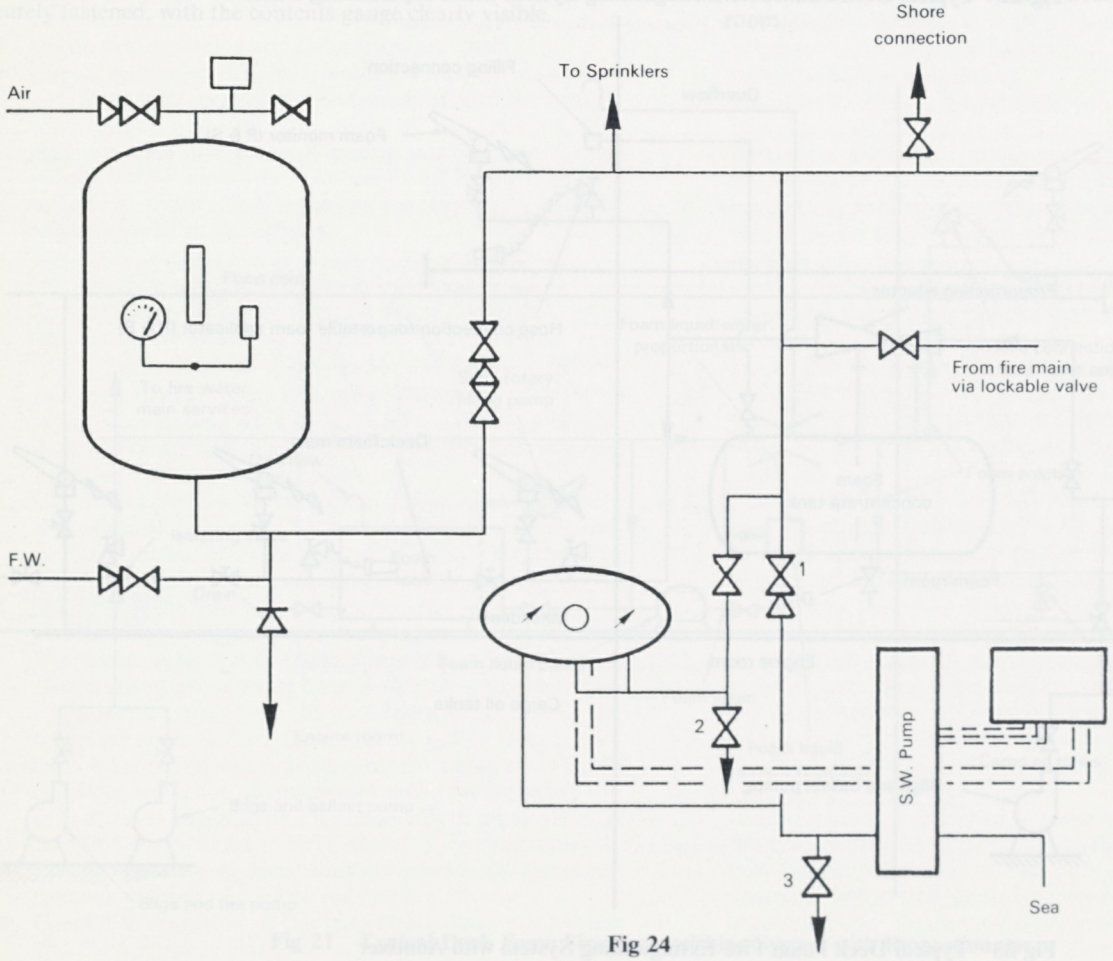


Fig 24

APPENDIX G
INERT GAS SYSTEMS

It is suggested the manufacturers test procedure be adopted for the initial testing/survey onboard new construction. It should be confirmed however this test programme covers the points enumerated in Appendix B of the L.R.T.A. paper 'Inert Gas and Venting Systems' by B.W. Oxford.

Annual surveys should be completed in accordance with Part 1, Chapter 3, Section 2.2.21 of the Society's Rules and Regulations.

ANNEX I
1978 PROTOCOL 1981 and 1983 AMENDMENTS TO SOLAS 1974

CONSTRUCTION AND EQUIPMENT REQUIREMENTS RELATING TO EXISTING SHIPS*

			1978 SOLAS Protocol Ships built before 1 May 1981			1981 SOLAS amendments Ships built before 1 September 1984		
Ship type	**Ship size**	**Subject of compliance**	**Chapter**	**Regulation**	**Effective Date**	**Chapter**	**Regulation**	**Effective date**
Passenger ships	Any	Carriage of goods vehicles and their personnel	—	—	—	II–1	16	1.9.84
Passenger ships	Any	Marking, operation: inspection of watertight doors	—	—	—	II–1	24	1.9.84
Passenger ships	Any	Entries in log	—	—	—	II–1	25	1.9.84
Tankers. chemical tankers, gas carriers	> 10.000 GT > 40.000 GT	Steering gear requirements Steering gear single failure criterion	II–1 —	29(d)(i) —	1.5.83 —	II–1 II–1	29.19 29.20	1.9.86 1.9.88
Passenger Cargo	Any > 500 GT	Response to initial fire alarms Response to initial fire alarms	— —	— —	— —	II–2 II–1	40 40	1.9.84 1.9.84
Crude oil tankers	> 70.000 GT	Fixed deck foam system and inert gas system†	II–2	60(d)(i)	1.5.83	II–2	60.4.1	1.9.84 or delivery of ship
Crude oil tankers	20.000 to 70.000 dwt	Fixed deck foam system and inert gas system†	II–2	60(d)(ii)	1.5.85	II–2	60.4.2	1.5.84 or delivery of ship
Crude oil tankers	20.000 to 40.000 dwt‡	May be exempted	II–2	60(d)(ii)	1.5.85	II–2	60.4.2	1.5.85 or delivery of ship
Tankers other than crude oil	> 70.000 dwt	Fixed deck foam system and inert gas system†	II–2	60(e)(i)	1.5.83	II–2	60.5.1	1.9.84 or delivery of ship
Tankers other than crude oil	20.000 to 70.000 dwt	Fixed deck foam system and inert gas system†	II–2	60(e)(ii)	1.5.85	II–2	60.5.2	1.5.85 or delivery of ship
Tankers other than crude oil	20.000 to 40.000 dwt‡	No requirement	—	60(e)	—	II–2	60.5	—

* Requirements relating to passenger ships built before 26.5.1980. Part F – Special fire safety measures for existing passenger ships – of Chapter II 2 of the 1974 SOLAS applies.

† See Regulation II-2/62.20 for tankers fitted with inert gas systems before or after 1 June 1981.

‡ Not fitted with tank washing machines with throughput > 60m³/h.

CONSTRUCTION AND EQUIPMENT REQUIREMENTS RELATING TO EXISTING SHIPS

			1978 SOLAS Protocol Ships built before 1 May 1981			1981 SOLAS amendments Ships built before 1 September 1984			1983 SOLAS amendments Ships built before 1 July 1986		
Ship type	**Ship size**	**Subject of compliance**	**Chapt.**	**Reg.**	**Effective Date**	**Chapt.**	**Reg.**	**Effective date**	**Chapt.**	**Reg.**	**Effective date**
Passenger ships Cargo ships	Any ⩾500 GT	Replacement of or additions to life-saving appliances							III	1.4	1.7.86 and 1.7.91
Passenger ships Cargo ships	Any ⩾500 GT	Survival craft emergency position-indicating radio beacons							III	6.2.3	1.7.91
Passenger ships Cargo ships	Any ⩾500 GT	Two-way radiotelephone apparatus*							III	6.2.4	1.7.91
Passenger ships	Any	Lifejacket lights							III	21.3	1.7.91
Passenger ships	Any	Immersion suits and thermal protective aids							III	21.4	1.7.91
Cargo ships	⩾500 GT	Additional liferafts							III	26.3	1.7.91
Cargo ships	⩾500 GT	Lifejacket lights							III	27.2	1.7.91
Cargo ships	⩾500 GT	Immersion suits and thermal protective aids							III	27.3	1.7.91
Passenger ships Cargo ships	Any ⩾500 GT	Retro-reflective material and life-saving appliances							III	30.2.7	1.7.91

* Apparatus need only comply with the frequency requirements of regulation IV/14.3

CONSTRUCTION AND EQUIPMENT REQUIREMENTS RELATING TO EXISTING SHIPS

			1978 SOLAS Protocol Ships built before 1 May 1981			1981 SOLAS amendments Ships built before 1 September 1984			1983 SOLAS amendments Ships built before 1 July 1986		
Ship type	**Ship size**	**Subject of compliance**	**Chapt.**	**Reg.**	**Effective Date**	**Chapt.**	**Reg.**	**Effective date**	**Chapt.**	**Reg.**	**Effective date**
Passenger ships Cargo ships	Any ⩾300 GT	VIIF radiotelephone installation				IV	4–1(a)	1.9.84			
Radiotelegraph ships	Any	Radiotelephone transmission and reception facilities				IV	10(g–2)	1.9.84			
Radiotelegraph ships	Any	Radiotelephone alarm generator*				IV	10(h)(iv)(l)	1.9.84			
Passenger ships Cargo ships	Any ⩾500 GT	VIIF radiotelephone installation energy source capacity				IV	17(b).(c)	1.9.84			

* For installations fitted prior to 1.9.86, fitting as determined by Administration.

CONSTRUCTION AND EQUIPMENT REQUIREMENTS RELATING TO EXISTING SHIPS

			1978 SOLAS Protocol Ships built before 1 May 1981			1981 SOLAS amendments Ships built before 1 September 1984			1983 SOLAS amendments Ships built before 1 July 1986		
Ship type	**Ship size**	**Subject of compliance**	**Chapt.**	**Reg.**	**Effective Date**	**Chapt.**	**Reg.**	**Effective date**	**Chapt.**	**Reg.**	**Effective date**
All ships	⩾150 GT	Magnetic compasses				V	12(b)	1.9.84			
All ships	Any	Steering compass and means for taking bearings				V	12(c)	1.9.84			
All ships	⩾1.600 GT	Gyro-compass				V	12(e)	1.9.84*			
All ships	⩾10.000 GT	Second radar	V	12(a)	1.5.81	V	12(h)	1.9.84*			
Tankers	⩾40.000 GT	Automatic radar plotting aid				V	12(j)(i)(2)	1.1.85*			
	10.000 to 40.000 GT	Automatic radar plotting aid				V	12(j)(i)(2)	1.1.86*			
All ships except tankers	⩾40.000 GT	Automatic radar plotting aid				V	12(j)(i)(3)	1.9.86*			
	20.000 to 40.000 GT	Automatic radar plotting aid				V	12(j)(i)(3)	1.9.87*			
	15.000 to 20.000 GT	Automatic radar plotting aid				V	12(j)(i)(3)	1.9.88*			
Ships on international voyages†	⩾1.600 GT	Echo-sounding device				V	12(k)	1.9.84*			
All ships	⩾1.600 GT	Rudder, revolution and propeller mode indicators				V	12(m)	1.9.84*			

* If structural alterations necessary. Administrations may allow fitting not later than 1.9.89 or first dry docking (regulation 12(t))

† New requirement if constructed before 25.5.80. NB. Composite pushing/pushed vessel unit regarded as single ship by regulation V. 12(s) of 1981 amendments.

ANNEX II

SAFETY GUIDELINES FOR CARGO SHIPS OF LESS THAN CONVENTION SIZE

Cargo ships of less than 500 Tonnes Gross Tonnage (except ships down to 300 GRT with respect to radiotelephony) are not covered by the SOLAS-Convention, and there exist no uniform regulations which provide an accepted international level of safety for such ships.

There is a considerable number of ships of this size sailing internationally under various flags and the Society is frequently asked to survey such ships on behalf of the Administration concerned and to issue appropriate certificates.

The purpose of the Guidelines is to provide a generally applicable code of safe practice in particular for safety equipment, radio installation and navigational equipment.

The Guidelines are intended to be applied with the consent of the Administration concerned, where no national regulations exist; they are furthermore offered for consideration by Administrations, who may wish to establish national statutory requirements for such ships or consider their revision.

It should be kept in mind that classification rules cover ships of all sizes. When applying these guidelines to ships not classed with the Society Administrations should ensure in addition a satisfactory level of safety with respect to construction, survey and maintenance of hull and machinery.

It should be realized that certain types of ships may require additional equipment or provisions, e.g. for fire extinction.

Equipment required should normally be of an approved type.

FIRE FIGHTING Proposed requirements for cargo ships of less than 500 GT in unrestricted and restricted trade	Unrestricted	Restricted
1. Fire pumps		
One main firepump independent from main engine.	X	X
One emergency hand pump outside machinery spaces.	X	X
2. Fire Hydrants		
Fire hydrants of sufficient number and so located that at least one powerful jet of water can reach any part of the vessel accessible to persons on board.	X	X
3. Fire Hoses		
At least three fire hoses not exceeding 15 m length complete with nozzles and couplings.	X	X
The nozzles shall be of an approved dual purpose type (spray/jet) with 12 mm diameter and an integrated shut-off valve.	X	X
4. Portable Fire Extinguishers		
At least three extinguishers in accommodation and service spaces.	X	X
At least two extinguishers in boiler rooms etc.	X	X
In machinery spaces one foam or powder extinguisher per each 750 kW of engine power (at least two but not more than six).	X	X
5. Non-Portable Fire Extinguishers		
At least one foam fire extinguisher ($>$ 45 litres) or one CO_2 extinguisher ($>$ 16 kg) in machinery spaces.	X	
6. Fireman's Outfit		
Two fireman's outfit.	X	

RADIO INSTALLATION	Unrestricted	Restricted
— Radiotelephone station	X	X
— A reliable clock	X	X
— Emergency light	X	X
— Battery charging device	X	
— Card of instruction on radio distress procedure	X	X
— Radiotelephone Transmitter	X	
— Receiver	X	X
— Radiotelephone distress frequency watch receiver	X	
— Radiotelephone alarm signal generating device & artificial antenna	X	
— Main and reserve source of energy	X	X (only) main source
— Main antenna (Safety wire not required)	X	X
— Spare Antenna, Tools, Insulators	X	
— VHF Radiotelephone installation	X	X
— Radio log	X	X
— Radiotelephone operator's certificate	X	X
— Station license	X	X
— Documentation	X	X

LIFE SAVING APPLIANCES	Unrestricted	Restricted
1. Survival Craft (rigid or inflatable lifeboats and liferafts)		
Survival craft for 100% capacity on each side	X	X
Extra survival craft for 50% capacity	X	
Automatic hydrostatic release for liferafts	X	X
2. Equipment of Lifeboats		
— a single complement of oars	X	X
— two spare oars	X	X
— one boat hook	X	X
— one and a half set of crutches attached to the boat	X	X
— two plugs for each plug hole attached to the boat	X	
— one bailer	X	X
— one bucket	X	
— a rudder attached to the boat and a tiller	X	X
— painters of sufficient length	2	1
— one sea anchor attached to a vessel with oil	X	X
— a watertight receptable containing	X	X
6 red hand flares	X	X
4 parachute signals	X	X
2 buoyant smoke signals	X	X
— hatchets	2	1
— a lamp with oil sufficient for 12 hours	X	X
— one first aid kit	X	X
— a waterproof electric torch suitable for morse signalling together with one spare set of batteries and one spare bulb in a waterproof container	X	X
— a food ration for each person	X	
— a water ration of $1\frac{1}{2}$ litres for each person	X	X
— a lifeline	X	
— compass	X	X
— $4\frac{1}{2}$ litres of vegetable fish or animal oil	X	
— a daylight signalling mirror	X	
— a jack knife	X	
— two buoyant heaving lines	X	
— manual pump	X	
— suitable locker	X	
— whistle or equivalent	X	
— one set of fishing tackle	X	
— one approved cover of highly visible colour to protect occupants	X	
— illustrated table of life-saving signals	X	
3. Life-Buoys		
Life-buoys incl. 2 with smoke/light and 2 with line	X	X
4. Life-Jackets		
One life-jacket for each person	X	X
5. Line-Throwing Appliance		
One line-throwing appliance with 4 rockets and lines	X	
6. Position Indicator		
One EPIRB installation	X	
7. Parachute Signals	12	6

NAVIGATIONAL EQUIPMENT	Unrestricted	Restricted
— Daylight signalling lamp	X	
— Barometer	X	X
— Thermometer	X	X
— Chronometer	X	
— Sextant	X	
— Magnetic Standard Compass	X	
— Magnetic Steering Compass (not necessary if standard compass is a projector compass)	X	X
— Spare Magnetic Compass	X	X
— Echo sounding gear	X	
— Hand line and lead	X	X
— Radar	X	
— Radio direction finder	X	
— Pelorus	X	X
— Binocular	X	X
— Mechanical outboard log	X	X
— Inclinometer	X	X
— International Code of Signals	X	X
— Search and Rescue Manual	X	
— Charts, as appropriate	X	X

TYPICAL STATEMENT ISSUED TO A SHIP OF LESS THAN 500 GT

Lloyd's Register of Shipping

REPORT OF CARGO SHIP SAFETY EQUIPMENT SURVEY

NAME OF SHIP: ..... GROSS TONNAGE: .....
PORT OF REGISTRY: ..... SIGNAL LETTERS: .....

This is a type of vessel excluded from the provisions of the International Convention for the Safety of Life at Sea, 1974, under Regulation 3, Chapter 1.

1. An inspection of the life-saving appliances on board indicated provision for a total number of .... persons and no more, viz:

   ..... capable of accomodating .... persons;

   ..... liferafts, for which approved launching appliances are not required, capable of accommodating .... persons;

   ..... lifebuoys;

   ..... lifejackets.

2. The liferafts were equipped in accordance with the provisions of the Regulations annexed to the International Convention for the Safety of Life at Sea, 1974.

3. The vessel was provided with a line-throwing appliance and portable radio apparatus for survival craft in accordance with the provisions of the aforementioned Regulations.

4. The inspection showed that the ship complied with the requirements of the said Regulations, where appropriate, as regards fire-extinguishing appliances and fire control plans and was provided with navigational lights and shapes, pilot ladder, and means of making sound signals and distress signals, in accordance with the provisions of the Regulations and the International Regulations for Preventing Collisions at Sea in force.

This Report is issued under the authority of the Government of .....

It will remain effective until .....

Issued at ..... the ..... day of 198

.....
Surveyor to Lloyd's Register of Shipping

Issued upon the terms of the Society's Regulations which provide that:

In providing services information or advice neither the Society nor any of its servants or agents warrants the accuracy of any information or advice supplied. Except as set out herein neither the Society nor any of its servants or agents (on behalf of each of whom the Society has agreed this clause) shall be liable for any loss damage or expense whatever sustained by any person due to any act or omission or error of whatsoever nature and howsoever caused of the Society its servants or agents or due to any inaccuracy of whatsoever nature and howsoever caused in any information or advice given in any way whatsoever by or on behalf of the Society, even if held to amount to a breach of warranty. Nevertheless, if any person uses the Society's services or relies on any information or advice given by or on behalf of the Society and suffers loss damage or expense thereby which is proved to have been due to any negligent act omission or error of the Society its servants or agents or any negligent inaccuracy in information or advice given by or on behalf of the Society then the Society will pay compensation to such person for his proved loss up to but not exceeding the amount of the fee (if any) charged by the Society for that particular service information or advice.

TYPICAL STATEMENT ISSUED TO A SHIP OF LESS THAN 300 GT

Lloyd's Register of Shipping

REPORT OF SAFETY RADIOTELEPHONY SURVEY

NAME OF SHIP: ..... GROSS TONNAGE: .....
PORT OF REGISTRY: ..... SIGNAL LETTERS: .....

A. This .....
is a type of vessel excluded from the provisions of the International Convention for the Safety of Life at Sea, 1974, under Regulation 3. Chapter 1.

B. An inspection showed that the Radiotelephony Equipment complied with the applicable requirements of the above Convention.

	Requirements of Regulations	Actual provisi
Hours of listening	.....	.....
Number of operators	.....	.....

C. The functioning of the portable Radio apparatus when provided for survival craft complied with the provisions of the said Regulations.

D. This report is issued under the Authority of the Government of .....

.....

It will remain effective until the .....

Issued at London on the .....

pro Secretary.

Issued upon the terms of the Society's Regulations which provide that:

In providing services information or advice neither the Society nor any of its servants or agents warrants the accuracy of any information or advice supplied. Except as set out herein neither the Society nor any of its servants or agents (on behalf of each of whom the Society has agreed this clause) shall be liable for any loss damage or expense whatever sustained by any person due to any act or omission or error of whatsoever nature and howsoever caused of the Society its servants or agents or due to any inaccuracy of whatsoever nature and howsoever caused in any information or advice given in any way whatsoever by or on behalf of the Society, even if held to amount to a breach of warranty. Nevertheless, if any person uses the Society's services or relies on any information or advice given by or on behalf of the Society and suffers loss damage or expense thereby which is proved to have been due to any negligent act omission or error of the Society its servants or agents or any negligent inaccuracy in information or advice given by or on behalf of the Society then the Society will pay compensation to such person for his proved loss up to but not exceeding the amount of the fee (if any) charged by the Society for that particular service information or advice.

ANNEX III

PASSENGER SHIP SAFETY INITIAL SURVEY PLANS REQUIRED

Hull Plans

1. Up-to-date General Arrangement showing passenger and crew numbers and disposition. This should include views above and below the double bottom showing the exact tank layout.
2. Arrangement and details of the watertight doors. This should show where the operation mechanisms are located.
3. Arrangement and details of sidelights, windows, doors, etc., in the shell together with their means of closing.
4. Arrangement of scuppers, sanitary discharges and sewage system.
5. Fire compartmentation drawing showing the disposition and details of all fire bulkheads and decks, insulation, stairways, escapes, doors, etc.
6. Combustible material volumes calculation.
7. Linings and deck covering plan.
8. Fire fighting drawing showing the disposition and details of all items of fire equipment such as hydrants, extinguishers, break glass alarms, firemen's outfits, axes, shore connections, etc.
9. Layout and details of sprinkler and/or detection systems. The individual heads and leads thereto should be shown.
10. Details and distribution of fixed fire fighting system in the holds, machinery spaces and special category spaces.
11. Fire extinguishing system showing the pipe distribution hydrants, pumps, valves, etc.
12. Ventilation and air conditioning layouts relative to fire zones, stairways, etc., and details of dampers, fan shut-down controls, etc.
13. Distribution of emergency lights and signs relative to escape routes, stairways, etc.
14. Bilge and ballast pumping arrangements including pumps, valves, suctions and discharges.
15. Air and sounding pipes – arrangement and details.
16. Lifesaving plan showing the positions and detail of all lifeboats, liferafts, distress signals, lifejackets, navigational shapes and sounds.
17. Navigation light layout and details.
18. Cross-levelling swimming pool dumping pipes and duct details, flaps and distribution.
19. Capacity plan showing up-to-date distribution of tanks above and below the double bottom.
20. Lines and body plans or offsets.
21. Hydrostatic curves or tables.
22. Inclining experiment report and full calculation.
23. Conditions of loading.

Although the foregoing list of plans seems a large one, in fact most can be incorporated on basic drawings starting from the small scale general arrangements.

'As Fitted' Safety Plans are required to be approved and placed on board to assist the crew in fire fighting, damage control or abandoning ship. The details of these are as follows:

24. **Fire Plan**
    This should be based upon fully up-to-date general arrangements of all decks and an internal profile to a scale of not less than 1/200. It should show the position and details of all fire insulation (i.e. bulkheads and decks), stairways, escapes, doors and clearly differentiate between bulkheads of A0, A15, A30, A60, B15, B0 and C class. Upon this plan the following should also be shown: positions and details of all items of fire fighting equipment such as fire extinguishers, hydrants, hoses, break glass alarms with their zones, detection heads, sprinkler zones and section boxes, firemen's outfits, ventilation dampers and shut-down controls, fire pumps, oil fuel shut-down positions, shore connections, CO_2 and halon bottle rooms, operating positions and areas covered, emergency generator and battery rooms, together with alarms or remote controls for any of the foregoing.
25. **Lifesaving Plan**
    This can be based upon the same 1/200 general arrangement as above but should have an external profile and the following: details and disposition of all lifeboats, ladders thereto, davits, liferafts, lifejackets, stairways and escapes, main and secondary exits from all compartments, emergency lights, radio – fixed and portable, navigation lights and shapes, doors, windows and sidelights in the shell, distress signals, lifebuoys, abandon ship signals, muster stations, etc., together with a statement of all persons on board, i.e. passenger and crew complement.
26. **Damage Control Plan**
    This plan should include both an internal and external profile and also show the exact disposition of all liquids in the tanks with details and distribution of the following: watertight doors with all their operating positions, alarms, light positions, etc., bilge pumps plus remote start, sounding arrangements, cross-levelling pipes or valves, bulkhead and shell sanitary discharge valves with their remote controls, swimming pool emptying valves, ship's side doors and refuse chutes. Particular details should be shown for all subdivision aspects, i.e. any steps or recesses in watertight bulkheads, B/5 penetration line, bulkhead deck, etc.
27. In addition to the above required plans, details and relevant certificates of such items as non-combustible materials, radio compasses, radar, direction finder, lifejackets, extinguishers, etc., plus all safety items on board, should be submitted.
28. Final Stability Manual (with inclining experiment report/calculation and permanent ballast – if fitted).
29. **Electrical Plans**
    Guidance to Electrical Plans required in addition to those in Part 6, Chapter 2.2.1.3 for Passenger Safety Certificate.
    1. All main and emergency lighting distribution board positions and their feeder cable routes from the main and emergency switchboards respectively.
    2. Positions of all emergency lights and all main and emergency lights sub-circuit details.
    3. General alarm system wiring schematic and locations of all alarms.
    4. Manual fire alarm system wiring schematic and locations of all push buttons.
    5. Wiring diagram of manual fire alarm indicating panel.
    6. Sprinkler system wiring schematic, including also supply arrangements to sprinkler pump, air compressor, etc.
    7. Wiring diagram of sprinkler alarm and indicating panel.
    8. Public address system wiring schematic, with positions of microphones and locations of loudspeakers.
    9. Wiring diagram of watertight doors including power, control and signalling systems where electric.
    10. Wiring diagram of supply and control arrangements for fire doors.
    11. Supply cable routes to emergency fire pump, emergency bilge pump and sprinkler pump.
    12. Load balance for the emergency generator and for the emergency battery under emergency conditions.
    13. As in (4) and (5) above, for any automatic fire detector system fitted.

30. **Radiotelegraphy, Radiotelephony and Safety of Navigation**
    1. Layout of Radio Room/Radio Equipment Room.
    2. Specifications of Radio and Navigational Equipment.
    3. Aerial (Antenna) Arrangement for Radio, Radar and Navigational Equipment.
    4. Layout of Navigating Bridge, Navigational and Radio Equipment.

5. Specification of Fixed Radio Installation in Lifeboat(s).

For ships undergoing major modifications, the above Plans will be required for the ship as a whole.
For ships where additions are being made or modifications are of a minor nature, the above Plans showing only the additions or modifications will be required.

The foregoing Plans are, in general, required by the Society for Passenger Ship Safety certification during construction. Variation may be accepted to suit shipyard's standards.
Transfer of Class cases where Society is authorised to carry out the Passenger Ship Safety certification, the foregoing Plans or their equivalent will generally be required.
Change of registration (flag) cases, on passenger ships already classed by the Society, Plans required will be by arrangement.

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Discussion

on the paper

CARGO SHIP SAFETY EQUIPMENT AND RADIO AND PASSENGER SHIP SAFETY SURVEYS AND CERTIFICATION

by

C. H. A. Marshall and J. V. Rugg

This Paper was awarded the 1987/88 L.R.T.A. Medal

Paper No. 3. Session 1987–88

FOR PRIVATE CIRCULATION AMONGST THE STAFF ONLY

Any opinions expressed and statements made in this Discussion Paper are those of the individuals.

Hon. Sec. A. G. Gavin
71 Fenchurch Street, London, EC3M 4BS

Discussion on the Paper

CARGO SHIP SAFETY EQUIPMENT AND RADIO AND PASSENGER SHIP SURVEYS AND CERTIFICATES

by

C. H. A. Marshall and J. V. Rugg

DISCUSSION

From Mr. J. R. G. Smith:

Seldom have I read a more confident opening to a Technical Association Paper. The second paragraph refers to the previous two classic papers on the subject by Messrs. MacMillan and Smart, thereby clearly implying that this too is a classic.

May I assure the Authors that I agree with their opinion. I doubt whether there is a more comprehensive paper on this subject anywhere in the world and I congratulate them on the considerable thought and effort they have put into its preparation. It will surely be one of the T.A. papers most used by our colleagues in the field. I would like to comment on four particular points and request the Authors' comments:-

017 Simultaneous Release Mechanism

There has been some argument in the past as to whether this should be automatic release and perhaps the authors would confirm that it should certainly not be. The philosophy of the two release system is that the 'off load' capability is for normal quick acting use when the boat is waterborne and the 'on load' capability is for emergency use when the lifeboat has failed to reach the water. The second release should also be capable of 'off load' use when waterborne in the event of failure of the normal mechanism. In order to prevent accidental release when air borne, the second system should only be capable of operation after taking deliberate action involving more than one movement. i.e. It should not be quick acting as required for the normal release.

018 Lifeboat Launching Appliances

Field Surveyors should take particular note that in the case of oil tankers, chemical tankers and liquified gas carriers, davits are to be capable of launching the lifeboat at a list greater than 20°, if found necessary on completion of damage stability calculations carried out in accordance with MARPOL 73/78 Annex 1, the International Bulk Chemical Code and the International Gas Code. Imagine the problems if davits were installed on the ship after having been tested ashore for compliance with the 20° requirement and then finding that the final angle of heel after damage is more than 20°. In order to avoid this situation, it is essential that the maximum angle of heel after damage is known as early as possible before such installation.

PART III. Convention Radio Requirements

The authors refer to the Future Global Maritime Distress and Safety Systems, which incidentally is now known as the Global Maritime Distress and Safety System, the 'Future' having been dropped. Would the authors agree that with this new technology and in particular satellite communications it should be possible in due course to replace radiotelegraphy with radiotelephony, even over long distances?

PART I.14 Computer Based Reporting

The authors state details regarding short term certificates which should be included in the narrative section of the report. Since other information such as dates of pyrotechnics and liferaft servicing are also required to be reported in the narrative section could these items be included in the standard format of the report so that the surveyors would require only to input the necessary dates? Also in this respect it is noted that existing ships other than tankers of 15,000 gross tons and over but less than 20,000 gross tons are to be provided with automatic radar plotting aids not later than 1st September, 1988. (See Page 30.) To assist our colleagues in the field could not the computer based system indicate this for all applicable ships with a directive that when fitted the Surveyors should report accordingly?

Finally, may I thank the Authors once again for this most comprehensive detailed and eminently practical paper.

From Mr. D. T. Boltwood:

My congratulations to the Authors for producing a very fine practical paper.

I would like to raise a few points which whilst more of a theoretical nature may help to broaden discussion.

1. In paragraph 018 the authors refer to the capability of lifeboat launching devices to function at angles of heel up to 20° and even higher if the final heel from damage stability calculations is greater. For Oil and Chemical Tankers this could mean 25° to 30° and for Gas Carriers 30°, all being static angles at equilibrium, thereby ignoring heel induced by rolling. Whilst accepting the philosophy behind such a requirement I cannot help but feel that safe evacuation of onboard personnel into lifeboats at such angles, even in an ideal sea state for evacuation purposes, is extremely optimistic and could not be achieved in practice. The requirement therefore appears unrealistic but have the Authors case histories which would allay my fears on this matter?
2. Recently there has been a deliberate attempt to quantify the survivability level of a dry cargo ship in terms of its subdivision through the use of statistics and probabilistic methods. It would not seem unreasonable to extend this approach into other areas of safety such as Life Saving Appliances and pose questions such as "what is the probability of safe evacuation given the current level of lifesaving appliances provided to a cargo ship" or more generally, " what level of risk does the current level of safety equipment placed aboard a ship actually represent"? This approach attempts to answer such questions and quantify the acceptable risk and set levels for design purposes.

   Are the Authors aware of any developments in this field? In connection with risk, I find it difficult to agree with the Authors' definition of safety. In my view only absolute safety can guarantee freedom from risk. Further I do not share their hypothesis that the highest standards, from

which I assume they mean absolute safety, would be 'comparatively easily achieved' if safety was the only consideration. In my view absolute safety is unachievable but perhaps they would comment on this point.

3. Recent casualties such as the "European Gateway" and "The Herald of Free Enterprise" have demonstrated that Ro-Ro Passenger Ferries are particularly vulnerable to short period capsize after water entry due to damage or other means. Also time-based Damage Stability analysis on cargo Ro-Ro ships has shown that the theoretical capsize time can be less than 1 minute. This makes evacuation impossible and importantly, appears to be contrary to the philosophy on which SOLAS is based viz, that the ship remains afloat for a sufficient time to enable safe evacuation. If this problem cannot be satisfactorily resolved by say, improved subdivision etc, until some time in the future, can the Authors suggest on a measure from the safety equipment viewpoint which could be introduced in the interim period to compensate for this apparent failure to comply with the spirit of SOLAS.
4. Finally, do the Authors consider the results of lifeboat drills meaningful when such drills are usually performed in unrealistic physical and environmental conditions?

From Mr. C. M. Magill:

I have read this paper from cover to cover – twice, one in its draft form and more recently its published form. It is not an easy document to read in this way but I doubt if it was ever intended that this should be the case. In common with previous ICD Papers the intent has been to provide guidance to Surveyors in the field concerning regulation compliance and what to look for in any aspect of a safety equipment survey. The information given with respect to each item on the two SE report forms achieves this aim admirably and the daunting bulk of the paper is then easily forgotten. Perhaps a detailed contents list of the enumerated items on the SE report forms would greatly assist use of the paper in the intended way.

Having acknowledged that the document is already very large I am now going to ask for further information to be given with respect to future development. Looking back at the sequence of IMO activity concerning fire and SE regulation development in the SOLAS Conventions, the '74 Convention chiefly established new requirements for passenger ships, the '78 Protocol dealt with tanker problems, the '81 Amendments dealt with cargo ships and the '83 Amendments with chemical and gas carriers together with a complete update of L.S.A. requirements for all ships. Due to this sequence of events it can now be found that fire and L.S.A. requirements for passenger ships are, in some instances, less onerous than those established for all types of cargo ships. Dead end corridor lengths and open lifeboats are two specific points. Would the authors care to comment on any expected revisions in these areas, or if they are considered necessary, and what are the areas where future development work has been identified as necessary?

The authors have been flattering in the reproduction of some condensed data from the '81 Amendments Fire Paper by Mr. Holland and myself. However, in Appendix B concerning portable fire extinguishers, an additional Table (number 8) has been added, to give a guide to the assessment of "equivalent" extinguishers. Use of this table could lead to the provision of extinguishers of an incorrect type since, in particular, a CO_2 unit for the 45 litre foam unit required in an engine room would not be acceptable. I appreciate the intent to provide some guidance for field surveyors faced with problems of replacing out of date or discharged extinguishers in remote parts and would suggest that the following note be added to Table 8 – "Equivalency to be assessed only in conjunction with acceptable types as shown in Table 6".

My congratulations on a well executed guidance document.

From Mr. G. W. Brown:

May I add my plaudits to those which have gone before on this excellent paper, very well presented this evening.

I would like to add one or two comments with particular regard to the 1983 Amendment Lifeboats, which may be of assistance to outport colleagues when carrying out surveys.

Firstly, surveyors should note that the lifeboats are provided with training and maintenance manuals which provide a good guide to the release, air support and water spray systems fitted. They also provide details as to the minimum allowable contents of air cylinders etc.

While examining release systems on these boats the Surveyors should also note that they are provided with purpose made pendents which must be shackled to the hooks and davit heads. This then allows the release systems to be operated without the boat's rapid disappearance over the side, which may lead, in the words of the Dept. of Transport, to "loss of confidence on the part of those watching."

A small point with regard to G.R.P. repairs, the Surveyor should remember that flame retardant resins should be used for all except minor internal repairs and the manufacturer's guidance should be sought if in doubt.

Lastly, one anomaly which seems to arise, when, on an existing ship, a serious accident results in the destruction of both the boat and the davit, then equipment complying with the 1983 Amendments should be fitted (Chapter III Reg. 1.4.3). This will result, if replacement takes place on one side of the ship only, in two types of release being used in contravention of Regulation 15.4, and perhaps the authors could comment.

If this paper provides as much assistance to the outport surveyor as George Smart's paper provided to me, then all the time and effort which have gone into it will be richly rewarded.

From: B. P. Sharman

The authors are to be congratulated upon their paper. It will serve as a useful guidance for Surveyors undertaking Safety Surveys. As with all documents of this type it is advisable to use it in conjunction with the referenced Convention Publications, i.e. 1974 SOLAS, COLREG 1972 etc.

The electrical installation plays an important role in the safety of the vessel under normal operation and is indispensable in an emergency. It falls to the Electrical Engineer to ensure that the arrangements are such that both roles can be met without hazard to personnel or risk of fire and 1974 SOLAS as amended 1983 Chapter II-1, Part D is cased in these terms. The general electrical installation is not covered in any great depth in the paper but I would however offer the following comments on the electrical items that are:

007 Navigation Lights

I have been led to believe that the chromaticity requirements of COLREG 1972 were not able to be met by oil lanterns which thereby excluded their use. This is reflected in the 1981 amendments to 1974 SOLAS, Chapter II-1, Regs 42.2.2 and 43.2.3 which requires the navigation lights to be fed from the emergency source of power. 1974 SOLAS (unamended) included the words "navigation lights if solely electric". As the paper addresses 1974 SOLAS what vessels under this convention may still have oil lanterns?

039 Emergency Fire Pump

Electrically driven cables from the emergency fire pump to the emergency generator are also not to be run through the main machinery spaces or spaces of high fire risk such as galleys.

058 General Alarm

For passenger ships it has been accepted the general emergency alarm be sounded through the public address system provided it is not possible to mute the loudspeakers when the

alarm is sounded. This arrangement whilst acceptable to many national authorities it may not be acceptable to the USCG. The authors may wish to confirm this.

060 Emergency Electrical Power

The arrangements described are applicable to cargo ships only. For passenger ships where the emergency source of electrical power is generator it is mandatory to provide a transitional source of electrical power which is to be an accumulator battery.

For both cargo and passenger ships the emergency source of electrical power may still be an accumulator battery. 1974 SOLAS as amended 1983, Chapter II-2, Regs 43 and 44 respectively specified what services are to be supplied in an emergency.

P003 Public Address System

This system may also be used to sound warning signals such as the fire and general emergency alarm (058 refers) either by using bells or klaxons or electronically generated signals. Each alarm is to be clearly identifiable which may require explanation notices in each cabin.

Sounding alarms through the public address/entertainment amplifiers is more onerous than speech or music it is therefore to be demonstrated that the amplifiers are capable of sounding such alarms for extended periods without overheating or damage.

APPENDIX D – HALON SYSTEMS

In addition to mineral insulated cables, fire resistant types to IEC Publication 331, Fire Characteristics of Electric Cables, have been accepted. From an outward appearance these may not appear very different to ordinary cables so in order to establish their suitability test reports may be required to be examined.

From Mr. B. H. Wong:

The Authors should be congratulated on their sequel to the previous papers by Messrs MacMillan and Smart and in this case their paper will probably remain a classic for a long time to come.

National Authorities and Ship Owners acknowledge the fact that the Society gives top priority to the Safety of Ships and those on board and this Paper further endorses that aim.

My question is directed to the Cargo Ship Safety Equipment during an Initial Survey. You state that some National Authorities publish their own National Regulations with different and most times, more onerous requirements e.g. the Singapore Requirements for additional lifejackets, additional set of Breathing Apparatus for ships other than Tankers over 10,000 GRT, requirement for additional 6-man liferaft for Tankers and Gas carriers over 3000 GRT and other minor differences in lifeboat equipment will not be immediately appreciated by other distant outport Surveyors unless they have read and digested the deviations of the various National Regulations.

We are aware of the differences listed in ICD/ICL 66 (Rev. 1), the Surveyors Procedure Manual and the Microfiche ICPM Remarks and References to various ICD/ICL circulars, but we consider an updated list in the form of ICD/ICL 66 (Rev. 1) to be necessary in order to include other countries' Regulations that vary from the SOLAS 74 Convention and its Amendments.

The fastest way to achieve this would be to enlist the help of the outports to liaise with the respective Flag Administrations and each will detail a list of items for HQ to compile. During a Change of Flag Survey where the Surveyor in some cases has less than 6 hours to complete all statutory surveys and fill up a new Rpt. SE1 this easy reference list will go a long way to assist him and clear his doubts.

On the subject of completing the New Rpt. SE1 during an initial survey could you consider (as you have done on Sheet 1 of Form 2092) highlighting on the other sheets the items required for ships built after 1/7/86 which will save the surveyor some time by not having to refer to the SOLAS Convention and your explanatory notes to confirm that these items are not required when he is completing the Report for a vessel built before 1/7/86. This convenient method will enable him to expedite the Initial survey under a tight schedule and also make the Owner aware why so many sections of the Report are not applicable to his ship.

From: D. H. Mann

The authors are to be congratulated on their mammoth task in provided a paper which will no doubt be useful to outport surveyors carrying out S.E. Surveys. The following observations are put forward mainly to assist Electrical Surveyors at the plan approval stage.

In PART II-1 059, concerning emergency stops, it is the practise on many ships to fit only 1 emergency stop for all Fuel and lube oil pumps and ER fans, boilers, incinerators etc., although I have seen ships with individual stops for each drive concerned (about 50). From an operational viewpoint the latter seems ridiculous although it does give selectivity, however, the former may also not be ideal as it inevitably causes a blackout causing the loss of illumination, main fire pumps etc. A collective shut off system for tanks using a master pneumatic or hydraulic system has of course the same effect.

Would the authors give their opinions as to the most practical method of arranging a minimum number of stops and tank shut offs e.g. segregating main propulsion, Diesel Alternators, other auxiliaries, separate stops for separate engine rooms etc.

In PART II-2 061, presumably the batteries referred to are those supplying transitional lighting and not emergency alternator starting batteries.

Lifeboat/Liferaft Launching Positions

In the past it has been necessary to arrange suitable lighting at both preparation (i.e. stowed) and embarkation positions. Presumably now that the requirements have been modified so that these positions are one and the same there is no longer a requirement for separate sets of lights. Could the authors please indicate suitable lighting arrangements?

From Mr. J. H. Parry:

I would like to congratulate the Authors on a very comprehensive paper, I am aware of the many hours of hard work and preparation it took. I know that it was the Authors' intention to produce a paper that will assist outport surveyors to carry out safety surveys which are becoming increasingly complex, I think they have achieved this end and hope that the paper will rapidly become a classic to stand alongside similar papers of the past. I have a few comments to make:

Under item 1.3 General Procedures, I would like to add that at passenger ship safety renewal surveys any permanent ballast is verified unchanged and is in accordance with that shown in the approved stability manual/ballast plan.

In the case where a cargo ship safety equipment survey is held and completed at one time do the Authors see the future possibility for the outport concerned issuing the full term certificates.

When liferafts of 180 kgs. or less are to be transferred from one side of the ship to the other, it's always been a bit vague to me what criteria is used for acceptance of the arrangement, could the Authors elaborate.

It was my custom at passenger ship safety renewal surveys to thoroughly examine 50% of all lifeboats including at least one of each type and size and including equipment annually so that 100% of lifeboats and equipment were examined every two years, with a record of boats examined being kept onboard, what are the Authors' opinions on this procedure.

In the appendices would the Authors care to give details of the procedures for conducting fire and boat drills.

Finally I would like to see an index of ICD/ICL letters which relate to safety equipment and surveys, I think this would be useful to outport surveyors as a quick and ready reference.

From Messrs. M. B. Christiansen and A. K. Almlund:

The Authors should be congratulated on the production of a very valuable paper for outdoors surveyors when conducting either initial or periodical survey of safety equipment.

It is believed though that some clarification of the interpretations might be useful.

PART I-12 section 7 talks about 1960 SOLAS Convention for all cargo ships of 500 gross tons and upwards, i.e. tons of 2.83 cubic metre. In 13 section 5 it says SOLAS 1974 require all cargo ships of 500 Gross Tons (G.T.) be provided with Safety Certificates. Are G.T. the same as in the 1960 SOLAS or do they refer to 1969 Tonnage Convention Regulation 3.

In SOLAS 1974 Chapter I Regulation 3 it says 500 tons gross tonnage (believed to be a 2.83 cubic metre and not G.T. (IMO). In 16(d) you are mentioning vessels of 500 GT or more issued with Rpt 10. Is this because in accordance with pre 1969 Tonnage no certificate necessary (i.e. G.T. bigger than GRT).

In Annex II, Safety Guidelines for Cargo Ships less than Convention size, it is mentioned Tonnes Gross Tonnage, GRT and in the table G.T. This is rather confusing for many and to cut the above down, clarification of what, where and when could be of great help. An example for a vessel (Danish), recently surveyed from this Port, might be useful in your understanding of our question.

M/S SAGAI AND ex KAROLINA LR NO. 8116130
1947 Tonnage 499.99 GRT
1969 Tonnage 1510 GT
The vessels were not equipped with a Safety Equipment Certificate.

PART I-1 4 and 5 mentions plans to be forwarded for approval. To help outdoors Surveyors it would be useful if HQ, after receipt of Request 1, could forward a list stating relevant plans, although it can be found in the applicable Parts of the Rules.

PART I-1 14 not understood since APM Part C Appendix 4 clearly shows, that outstandings have to be reported under "Statutory Details" and those dealt with for commencement have to be reported in narrative section.

If the survey is not completed, why leave all accepted items for the next Surveyor to report, like doing the same survey twice. Maybe our interpretation of I14 are incorrect, but some clarification of the subject might be useful, since a major portion of a survey may have been done, before any found discrepancies can't be dealt with.

APPENDIX B

Para 1 mentions that the portable extinguisher has to be painted in accordance with table 7. Although very helpful when conducting surveys, it is found from experience, that most extinguishers are painted red. Please clarify, if the painting of the extinguisher in accordance table 7 is a requirement or only recommendable.

Para 2 Section 1 and 2 says that the same type of extinguisher Water (soda acid), should be tested by two different modes, please clarify this.

APPENDIX D
Periodical Surveys and Tests

Para 1 – Cylinders to be weighed or the level of liquid gauged. How much may the loss be before the cylinders shall be recharged? Previously it was 10 per cent.

From Mr. G. Smart (Retired):

Having studied Paper No. 3 of the 1987–88 Session, the immediate reaction is one of acclaim and praise for the authors who have produced an excellent document which will no doubt be received with great enthusiasm by the outdoor Surveyors world-wide. It can be appreciated that a good many Surveyors, especially those not having experienced such work, will have read the paper and feel some apprehension and alarms at the thought of completing the twenty-odd pages of the SE1 and carrying out the seemingly tedious work of examination and testing in order to complete the survey during the same period. It should, however, be borne in mind that the items listed in the SE1 cover all types of equipment and only the relevant parts require to be completed according to items actually provided on board the ship under survey. It must be stressed that a knowledge of the relevant Convention requirements and experience in the type of work is essential in order that such a survey can be dealt with in a successful and satisfactory manner.

In its 102 pages the paper contains amassed information on Cargo Ship Safety Equipment and Radio in addition to Passenger Ship Safety Surveys and Certification and it is thought that an index (a lengthy and laborious task) would have enhanced and completed the work of reference and eased the reader's task in locating particular subjects contained therein. Additionally it is thought that separation of Cargo Ship from Passenger Ship requirements might be advantageous as the two are entirely independent and a Surveyor can deal only with one or the other.

PART II on page 80 gives an excellent description of Convention Radio Requirements and it is submitted that some mention be made of the survey of Radiotelegraphy and Radiotelephony Installations which are required annually, giving the extent of the Surveyors involvement in the specialised work entailed.

Item 025 (page 47) refers to liferafts illustrated on Figures 1 to 5 (pages 34 to 38) and it is important that inflatable liferafts and inflatable boats be serviced annually only by an authorised agent of the manufacturer, as cases have occurred where inflatable liferafts have been serviced by unauthorised and incompetent parties particularly in the Far East, and the liferafts have later been found improperly packed together with numerous other defects which would have resulted in the liferaft being useless had it been required for use as a life-saving appliance. Rigid liferafts on the other hand need to be examined by the Surveyor during the survey of Safety Equipment with all equipment being checked against the SE1 and pyrotechnics renewed as necessary.

Many other points may arise during a Cargo Ship Safety Equipment Survey at the change of flag of an existing ship as the National requirements of several Administrations are more stringent than those laid down by the Convention. Guidance should be sought from HQ regarding these matters.

Finally, my thanks to the authors for giving me the privilege of reading their excellent paper which must have taken many hours of absorbing work outside office hours and other comments made at the written discussions are awaited with interest.

From Ulsan Surveyors:

May we first of all congratulate the authors on a very interesting and informative paper.

It has been a long time since G. Smart's paper on the same subject was published in the 1970–71 Session, dealing with the 1960 SOLAS Convention. Since that time the Regulations have been amended substantially on three occasions, and little official guidance has been made available other than the numerous ICD/ICL letters which have been issued. The section on SOLAS in the Survey Procedures Manual, it is noted, is confined to statements on the applicability of the convention and its status, and is hardly sufficient to be of any practical assistance in carrying out surveys; so firstly we would like to ask when can we expect to receive comprehensive instructions to the surveyors such as those in the SPM Load Line Section?

In Ulsan the surveyors are dealing with both new construction (initial surveys) of cargo ships and periodical surveys (annual), intermediate and renewal surveys) on existing ships. Some of the problems encountered here have undoubtedly been found in other ports, but nevertheless we would appreciate the authors comments and guidance on the following:

NEW CONSTRUCTION

1. Lifeboats
   It is concluded, but please confirm, that lifeboats intended for oil tankers are required to comply not only with Regulation 46 (fire-protection i.e. fitted with water-spray system), but also with Regulation 45 (self-contained air-supply system) as the wording in the SOLAS regulations (particularly Reg. 26) is not explicit.
   We question whether CO_2 portable fire extinguishers are suitable for use in totally-enclosed lifeboats – is CO_2 not asphyxiating in enclosed spaces? We normally recommend foam extinguishers.

2. Lifeboat Davits
   Ships officers and crew appear to be reluctant to adopt the new regulations which require the lifeboats to be boarded and launched from the stowed position, and would still prefer to board the boat after the davits have been turned out and the boat lowered to, for example, the main deck. In fact several officers who have operated ships in the Gulf under the threat of missile attack have advised that they prefer to muster on the main deck under the shelter of the boat deck. Controlled lowering of the lifeboat when fully loaded from the stowed position can be a tricky business even in calm conditions since this requires an even application of the winch brake whilst turning out the boat from within the lifeboat itself which has a tendency to swing on the hooks.
   Please advise whether additional arrangements to board the lifeboats (provision of bowsing tackle etc.) at the main deck are still permitted under the new regulations.
   We have found it important to check the rate at which the remote control wire to the lifeboat pays out, as if this is not in sequence with the lifeboat falls a point is reached where the lifeboat becomes immobile halfway to the water.

We have devised our own checklist for initial lifeboat davit on board tests and a copy is enclosed for your perusal and publication if merited.

Advice would be appreciated on how to check that the lifeboat can be lowered over the ship's side against 20 degrees of adverse list, as the chocking of the davits at 20 degrees would appear to be more onerous than a real 20 degree list.

It is recommended that the embarkation rope ladder, which is normally arranged in way of the lifeboat, is rigged before lowering the boat in the adverse list test to ensure the boat and skates clear the ladder steps; if a problem of interference is found the rope ladder can be re-located just forward or aft of the original position.

Also, as the final angle of heel in a damage condition is seldom known early in the design stage, what do you do if this exceeds 20 degrees? – new davits may be necessary!

We are surprised that the revised report SE1 still mentions at least two lifelines fitted to the davit spans as we believed these no longer necessary when enclosed lifeboats are fitted – please clarify.

3. Survival and Training Manuals
   The contents of these documents provided by shipyards leave a lot to be desired. Is it possible to obtain samples which could be used for guidance, or is this a matter solely for the owners?

4. Navigation Lights
   Most tankers are now built without a forecastle, but with a considerable sheer on the upper deck forward. Some Administrations (for example the UK Dept. Transport) we believe require the height of the foremast light to be measured above the actual deck and in one case a foremast light was alleged to be below Rule height because of this. (The Society's recommendation is to neglect sheer and camber.) Is a uniform interpretation of this regulation available?

5. Signalling Apparatus
   In this modern age when the majority of ships are required to carry two radars, one with automatic plotting aids, is not the fitting of a manually operated forecastle bell and a gong on the bridge somewhat out-of-date. Are there not more suitable electronic signalling devices available which are more appropriate?

6. Firemans Outfits/Foam Tanks use with Portable Applicators
   The requirement for rubber boots and gloves (electrically resisting) would seem to conflict with the requirement for firemans' suits to be fire resisting. One can imagine the fireman beginning to skate on the deck as his boots begin to melt, or is it assumed that water on the deck will keep his soles below melting point? Similarly, we have found plastic tanks provided for engine room portable foam applicators and is noted that the Rules do not require these to be of steel; the possibility of the bottom melting out of the tank has been pointed out to the shipyard to no avail.

EXISTING SHIPS

1. Surveys
   After reading the paper it is concluded, if not already known, that to carry out a complete Safety Equipment survey is a formidable task. The regulations are framed such that the onus is on the surveyor not only to verify that the equipment is on board and in working order, but also that the crew are familiar with its operation and maintenance. As you are well aware, ships are spending shorter and shorter periods in port and at such times the crew are often fully occupied with cargo-handling and other tasks, if not on leave to take advantage of shore facilities. This makes the survey even more difficult to conduct and several visits are often required to complete a survey.
   We would like to know if the authors can advise the expected time to complete the safety equipment annual/intermediate and renewal surveys on, for example, a typical panamax size bulk carrier and oil tanker.
   Further, it is noted that the surveyor must satisfy himself at annual and intermediate surveys that all the equipment remains in a satisfactory condition. Could the authors provide some guidance on which items can be generally rather than thoroughly examined at such surveys – perhaps the checklists promised in ICD/ICL 214 will answer this one?

2. Liferaft Servicing
   We have encountered difficulties when Agents have advised owners to have liferafts service stations not recognised by the manufacturers and ourselves and as a consequence short-term certificates have been issued with conditions requiring the liferafts to be serviced again. Quite understandably, owners become upset about this. We would be interested to know whether other outports maintain and circulate a list of recognised service companies for liferafts, fire extinguishing equipment, radio equipment etc.

3. Emergency Steering Position
   Clarification of this subject in particular would be appreciated: Does the emergency steering position have to

be on the steering gear flat, or can this be another position on the Bridge? What constitutes acceptable heading information (other than a second gyro compass) on both new and existing ships?

4. Reports
   It has been practiced in this port to complete a report SE2 at initial/annual/intermediate and renewal surveys since it would appear necessary to record all service dates. In this respect, the necessity to include a sentence with all these dates in the existing ship report narrative makes a heavy burden for both the surveyor and the computer operator – when can we expect to receive a proforma for this?

In conclusion we wish to acknowledge the assistance of the HQ/ICD Safety Section to the field surveyors as their prompt response to calls for advice are much appreciated.

From LR Bremerhaven Surveyors:

During study of your recently published T.A. Paper No. 3 session 87/88 a number of questions arose, which could not be fully answered by discussing the queries with colleagues.

Therefore we felt urged to prepare the following list of questions, kindly asking you to advise us in this matter.

1. Is it generally possible to carry oil lanterns as navigation lights on cargo ships 500 G.T. and upwards (new and existing) only?
   Explanation of our question: Colregs 72 do provide requirements for lanterns other than electrically powered (Annex I, 10 (c) and 11). Colregs 72 do not specifically exclude the use of non-electric lanterns.
2. If electric navigation lights are fitted, do they have to be of double bulb/two tier/or similar construction, or will simple single filament bulbs satisfy the rules?
   Explanation of our question: Colregs 72 do require navigation lights to be set from sunset to sunrise (rule 20 (b)). In your paper you explain, that duplex type lights are a generally accepted arrangement. This does not exclude in our opinion the use of single lights plus the provision of spare electric/non-electric lights or spare bulbs ready for use as an acceptable method.
3. If electric navigation lights are fitted and non-electric lights kept as spare lights, are the electric lights required to be powered by the emergency source of power of ships built before 09.84?
   Explanation of our question: In your paper you state that SOLAS 74 required electric navigation lights fitted on board of cargo ships 5000 G.T. and upwards to also be powered from the emergency electrical source, but SOLAS 74, Ch. II-I, Reg. 26 only states that navigation lights if solely electric need power supply from the emergency source. Spare non-electric navigation lights do mean in our opinion, that the source of power is not solely electrical, and therefore an emergency power supply to the navigation lights does not seem to be required.
4. Since which date is double wiring required from the distribution board to the navigation lights?
   Explanation of our question: The latest rules part 6, Ch. 2-2, Section 3.1.5 require a switch over arrangement to an alternative circuit to be provided for the navigation lights. Assuming that duplex type/double bulb or similar are required and fitted, and treated as 'duplicate' arrangement then the rules part 6, Ch. 2-1, Section 2.5.1 require for essential services two individual circuits separated throughout their length as widely as practicable. Navigation lights are treated as essential services in accordance to Part 6, Ch. 2-2, Section 1.7.1. Neither SOLAS 74 nor the 81 or 83 amendments do, to our knowledge, mention double wiring.

We believe your answers to above questions will help us to settle the queries mentioned at the beginning of this letter.

From J.J. Stansfield:

A Surveyor's file was so much simpler in the days when George Smart presented his excellent LRTA paper in 1971 but the present authors have made a valliant attempt to produce a comparable paper guiding surveyors through complexities of the latest regulations.

I appreciate the work involved in the preparation of such a paper and variations of opinion of what should be included or omitted is bound to occur and so my comments are not intended to criticise but to seek clarification of some aspects of the paper.

Despite the title of the paper, I note that the major proportion is devoted to Guidance on Completion of the SEI but interspersed with comments and guidance for carrying out Safety Equipment Surveys. I think that for easier reference, the paper could have been split into the guidance notes for completion of the report and a separate part for guidance notes for carrying out surveys, especially for the L.S.A. aspects as it is noted that many of the Appendices bear a remarkable similarity to these already available in Messrs Holland's and Magill's previous paper.

The layout of the report appears straight forward but I am surprised that it is considered necessary to include the sketch for position of the Navigation Lights and surely the answer to paragraph 2.7.1 must always be "Yes"? Do so many cargo ships today have more than 2 lifeboats to warrent the 4 columns of sections 3.5 and 3.7 and the column for 'No provided' in section 3.18 is a little confusing but otherwise there should be no serious problem in completing the report satisfactorily.

There are a few points arising from the text which I would like clarified. No mention is made of the difficulties of ensuring adequate charts are supplied (ref. ICD/ICL 189). It is sometimes impossible for the surveyor to know what charts should be on board. I would have thought that a signed statement by the Master to confirm that he is satisfied would solve the problem and place the responsibility in more qualified hands. In paragraph 006(b)(ii) it is concluded that the "efficient fog horn" refers to the ship's whistle.

Will the authors please confirm that Accommodation Ladders (paragraph 010) do not come under any requirements so far as statutory certificates normally issued by the Society are concerned, unless, as stated, they form part of the pilot boarding arrangements.

Regarding the section on lifeboats, as I have stated earlier, I think that it would have been preferable to keep the text to the requirements of the present convention and to include the comments re survey of existing boats and the sketches of earlier SOLAS requirements separate. This section could then also include advice regarding the launching of free fall lifeboats. As I understand the easiest way to carry out the realistic lifeboat drill in these boats and to reduce the impact on the water is whilst the vessel is underway ahead. It is certainly not normally possible to release the boat in port during a Safety Equipment survey, so what should the surveyor do?

There is one aspect of the 1983 Amendments which I do not agree with and which I think is fraught with danger rather than enhancing safety and that is the Simultaneous Release Mechanism for lifeboats. In theory the idea is good but in practice, as accidents have already occurred, more are sure to happen as the equipment becomes older if proper maintenance is not carried out. On older existing ships which have lifeboats with remote releasing mechanism rarely, even on well maintained boats, have I found the system 100% efficient and the crew usually prefer to release the hooks by hand. A surveyor will have to be very careful when insisting on testing these systems because it would be very unfortunate if an accident occurred.

Regarding liferafts, I appreciate the clarification regarding fitting of weak links on painters. The 1983 Amendments are more explicit than the original 1974 SOLAS but I have tended to be guided by Reg. 23 alone without consideration of Reg. 38.6.1 and ensured that the painter was attached to the vessel usually

to the supporting frame of the liferafts, as in fact shown on Operating Instructions published by Viking (now obviously out-of-date). Nevertheless would a weak link be required for each liferaft on a multi-storage rack on an existing passenger ship?

In paragraph 027 a note could be added regarding the recommendation that a davit launchable liferaft be available for training purposes which is not part of the ship's life saving equipment.

With reference to paragraph 35 I wish that the manufacturers of self-activating light and smoke signals could be persuaded to print the date of manufacture/expiry somewhere it is not bleached out by the weather.

Turning to the Record of Passenger Ship Safety Equipment, it is a very welcome development to have a list of equipment for a Passenger Ship and one which is, amazingly shorter than that for a Cargo Ship. But the record by itself is not sufficient and surveyors who are carrying out Passenger Safety Surveys should be aware that they must consult the Safety Plans as well.

It is difficult to design the layout of a report to cover the wide range of type and quantity of safety equipment items on a Passenger Ship, and so, in my view, the report could have been in a more flexible format especially regarding listings of liferafts and fire fighting arrangements. It all depends how much detail is required, for example for item 053 is the position of each sprinkler station to be reported or is the general description of the system only required item with reference to the Fire Control Plan for the details?

The same comments apply, as for Cargo Ships, regarding the sketch of the Navigation Lights but it would have been more appropriate if the sketch could have at least resembled a passenger ship.

It is noted that there is no reference in the report to the draught stops, fire dampers in ventilation ducts, cross flooding arrangements or Swimming Pool Dumping Valves. Is there a reason?

In the text of the paper, in order to clarify paragraph P001, the definition of Long and Short International Voyages could have been given as it can cause confusion and a ready reference is always useful.

Will the authors please clarify where the duplicate set of fire plans should be placed on a Passenger Ship.

More guidance could have been given on conducting a Passenger Ship Safety Survey, for example when checking the operation of bulkhead valves it is not sufficient to see the system being operated from the bulkhead deck but the closing of the valve itself should be verified whilst the system is being operated from the bulkhead deck. Although there is nothing obscure in carrying out these surveys I believe even more vigilance is required than on a Cargo Ship as the majority of the lives potentially at risk are of people not familiar with the finer points of safety procedures. A sound knowledge and understanding of the requirements is desirable so that a good working relationship can be developed between the Safety Officer and the surveyor.

In conclusion could the authors please comment on possible future developments, for example, further use of the Marine Escape Slides on Passenger Ships and the changes which may result in Radio Survey when the Future Global Maritime Distress and Safety System is developed, and also give a brief indication of any new regulations affecting safety equipment surveys which are likely to be implemented within the next few years in addition to those already announced as per Annex I.

AUTHOR'S REPLY

The Authors wish to thank all those colleagues who have found the time and taken the trouble to contribute to the written discussion of the subject paper.

All comments and questions were much appreciated and in total can only help to increase the usefulness of the document.

We feel sure that like ourselves many colleagues worldwide will note with pleasure the contribution from George Smart who although retired for some years now still maintains an interest in the subject matter of the paper.

We would comment as follows on the questions posed:-

To Mr. J.R.G. Smith (HQ):

017 Simultaneous Release Mechanisms

It is correct to say "Automatic Release" of the lifeboat from the falls is not acceptable. That is not acceptable at the present time.

To date Lloyd's Register has not accepted an automatic release, i.e. a release arrangement which does not require some positive action to be taken by a member of the boats crew before the hooks are released from the falls.

At least one major Administration has in fact categorically rejected "Automatic Release".

It can however be confirmed that the Society is at present actively involved with the examination of plans for approval of an "Automatic Release" arrangement in compliance with the requirements of the amended Chapter 111 of SOLAS 1974.

018 Lifeboat Launching Appliances

After the subdivision section have examined stability calculations for oil tankers, chemical tankers and liquified gas carriers, if necessary the Builder is alerted to the requirement that launching appliances are to operate satisfactorily at the final angle of heel after damage should this be in excess of 20 degrees. The fully equipped lifeboat, loaded with the full complement of persons it is certified to carry, should be able to be launched from the stowed position to the water.

Part III Convention Radio Requirements

Yes without question radiotelephony will replace radiotelegraphy. It now has several years excellent commercial service via inmarsat – the International Maritime Satellite Organisation – on which to build safety communications in the years ahead.

High speed data and facsimile transmissions will augment telephone conversations which will form an extension to the ship of the present International Communications Service which we all take for granted.

PART I.14 Computer Based Reporting

As you are aware you are talking to the converted. We would however ask that now the system is "up and running" it should be "fine tuned" at some time in the future and outports should be involved when discussing areas where improvements can be made. Very careful consideration should be given to all suggested improvements before any are rejected. We would hope that any upgrading of the system would include as a top priority, the introduction into the system of screen formats of report forms.

This would significantly reduce the workload of outport staff as currently, in some instances, they produce a paper report for retention in the outport as well as the computer report for submission to HQ.

"Reports" in paper form would then be produced only when required and the need to distribute worldwide and store paper reports would no longer exist.

To Mr. D.T. Boltwood (HQ):

Whilst specific case histories of evacuation of ships by lifeboats at extreme angles of heel, in excess of 20 degrees, cannot be cited, we feel there most probably are examples to be found. Whilst accepting Mr. Boltwood's apprehension it could be argued that it would be extremely negligent of a national authority to wash its hands of a lifeboat launching requirement

simply because a ship assumes an angle of heel after damage of more than 20 degrees. In any case we are given to understand from some experienced mariners that the preferred evacuation craft in such circumstances would in fact be inflatable liferafts.

Apart from the continued scrutiny, at IMO, of ship safety in general we are not aware of any detailed study into a probabilistic assessment relating L.S.A. to evacuation risk.

SOLAS only provides a datum level for damage stability and assumes seas are calm, there will be no wind, no passenger heeling moments, damage penetration is of a defined extent etc. These assumptions are of course due to be changed at IMO, in the not too distant future, and will become more onerous. This will not mean however that all possible weather and sea conditions and damage penetrations will have been anticipated. It would appear therefore that a constant update of requirements is inevitable as, unfortunately, accidents continue to occur.

Various proposals have been put forward with a view to improving the attitude after damage of the existing Ro-Ro fleet. These include filling void wing spaces with foam, fitting automatic inflation collars around the ship, installing portable W.T. bulkheads in the Ro-Ro decks. All these and the many other ideas to improve the ship's safety have merit but the practical and operation aspects have yet to be proven.

Of course we consider lifeboat drills meaningful, as are fire and damage control drills. Officers and crew are part of the safety function of a ship. If they are unable to demonstrate their ability to efficiently use the safety equipment provided under ideal conditions, what chance in an emergency?

To Mr. C.M. Magill (HQ):

As indicated in part of the reply to Mr. Boltwood, IMO has regulations constantly under review. We would anticipate in the not too distant future a re-assessment of the fire safety aspects of passenger ship giving emphasis to the latest design requirements incorporating atriums and other modern features.

We would also like to see some account being taken of the advances in sophisticated fire detection and extinction equipment, the extensive range of incombustible materials, and new insulations now available, with a view to a possible re-assessment of the 40 metre fire zone. Perhaps the fire sub-division of the ship could be dealt with in a different way by taking into account the number of persons normally within a zone and the protected escape arrangements available to them?

The maximum permitted length of dead-end corridors in cargo ships and passenger ships carrying not more than 36 passengers is 7 metres. In passenger ships carrying more than 36 passengers, the maximum allowable is 13 metres. Accommodation areas in large passenger ships are generally located within structure of far greater beam than cargo ships or small passenger ships. The usual configuration of these state room areas on the larger ships is four rows of cabins, two outboard, with each inboard/outboard pair served by one passageway. This arrangement is simple and provides an easily remembered straightforward escape route. To incorporate a reduced dead end corridor length on these larger ships may lead to more complex arrangements to the detriment of escape.

Open lifeboats may be retained on existing passenger ships but all '83 built passenger ships are required to be fitted with partially enclosed boats as a minimum. The "cargo" of a passenger ship must not be forgotten. It consists of people of every age, shape and physical characteristic available. We feel that, in an emergency situation, where evacuation of the ship has to take place within 30 minutes it would be more efficient and psychologically easier to embark passengers into semi rather than fully enclosed boats. The risk of these boats having to transit burning oil or areas of dangerous chemicals or gas when leaving the ship is also considerably less than from some cargo ships.

Mr. Magill's points with respect to fire extinguishers are concurred with.

To Mr. G.W. Brown (HQ):

The points raised are noted with thanks. We are sure that most of our younger colleagues will insert a reference to the substance of your contribution in the space provided on each page of Part II of the paper.

The point about replacement equipment is noted. If an existing ship should need to replace both the davit and associated lifeboat the replacement equipment, and recovery appliance, are required to comply with the applicable requirements of the revised Chapter III of SOLAS 1974. (Reg. 1.4.3. refers).

Compliance with this requirement would however conflict with Reg. 15.4. if the original lifeboat and davit remained fitted on the other side of the ship.

To date we are not aware of such a situation having occurred. Hopefully the appropriate "IMO" sub-committee may well have considered the potential conflict of requirements before the situation arises. It should be mentioned that an existing lifeboat considered beyond repair may be replaced by a similar lifeboat providing the original davit remains efficient.

Likewise if an original davit is damaged, it may be replaced by similar equipment providing the original lifeboat remains efficient.

To Mr. B.P. Sharman (Croydon):

Mr. Sharman has raised some very valid points of which many non-electrical surveyors may not have been aware.

We would respectfully refer Mr. Sharman to the opening remarks, to the Bremerhaven surveyors contribution, in the latter part of this discussion paper with respect to his question on Oil Navigation Lights.

To date we have not experienced any problems with the USCG accepting the general alarm being sounded through the ships public address system.

To Mr. B.H. Wong (Singapore):

The question of how to make available to all outports all of the national variations and additions to the requirements of SOLAS is constantly under consideration.

We would hope that perhaps in the not too distant future such information would be entered onto the computer and hence be readily available to all computer linked outports and their associated manual satellite ports.

Efficient updating would be an added advantage of such a facility.

It was decided that the revised SE1 (5/87) should only be used for new ships. Subsequently it was appreciated that ultimately stocks of the SE1 (03/81) would be exhausted and of necessity form (5/87) would need to be used for "existing ships" being surveyed by the Society for the first time with respect to safety equipment. (ICD/ICL No. 214 refers).

The solution to the problem you foresee with regard to equipment on "existing ships" would appear to be that all of our colleagues should obtain for their personal records a copy of form SE1 (03/81) before supplies are exhausted, which would provide a ready reference document when dealing with "existing ships".

It is worth mentioning that lifeboat equipment is an area where several items of equipment previously required in open lifeboats are no longer required in totally enclosed lifeboats and hence have no space for a specific entry on the SE1 (5/87). Such items should be recorded on Page 21 of form SE1 (5/87).

The list below may be of use.

RETRO FIT REQUIREMENTS FOR EXISTING SHIPS

Items of equipment generally required to be retrofitted to

EXISTING SHIPS although not all specifically required so to be by the Convention.

SOLAS 1960

Ship Equipment:

(a) At least one International Shore Connection.
(b) At least 12 parachute distress signals.
(c) At least two lifebuoys to be fitted with smoke in addition to lights.
(d) Approved liferaft or liferafts for half the total number of persons on board except tankers of more than 1600 GT but less than 3000 gross tons.

Lifeboat Equipment:

(a) One whistle (or equivalent).
(b) One set of fishing tackle.
(c) One approved cover of a highly visible colour capable of protecting the occupants against injury or exposures.
(d) One copy of the illustrated table of lifesaving signals.
(e) Four parachute signals.
(f) Means to enable a person in the water to climb into the lifeboat.
(g) One rust proofed graduated drinking vessel.

Radio:

(a) Sufficient aerial wire and insulators to enable a suitable aerial to be erected in addition to the mains and reserve aerials.
(b) An instrument or instruments for measuring A.C. volts; D.C. volts and ohms.

SOLAS 1974

Ship Equipment:

(a) A Fire Control Plan.
(b) At least two fireman's outfits each with personal equipment.
(c) All ships including tankers to carry liferafts for at least 50 per cent of the persons on the ship.
(d) Automatic float free and inflate arrangements for liferafts.
(e) A liferaft for at least six persons to be carried forward on vessels with no amidship superstructure and having a Registered Length of 150 metres or more.

Radio:

A watch keeping device able to operate on 2182 kHz.

1981 Amendments to SOLAS 1974

Safety Equipment:

(a) A duplicate set of Fire Control Plans stored outside the deckhouse.
(b) At least four fireman's outfits in tanker of 500 gross tons or more.
(c) A standard magnetic compass.
(d) A steering magnetic compass.
(e) Means of communication between standard compass and normal navigation control position.
(f) Means of taking bearings through 360 degrees.
(g) Magnetic compass table of residual deviations.
(h) Spare magnetic compass.
(i) Gyro compass.
(j) Radar one or two.
(k) Radar plotting facilities.
(l) Automatic Radar plotting aids.
(m) Echo sounder.
(n) Speed and distance indicator.
(o) Rudder angle indicator.
(p) Propellor revolutions counter.
(q) Propellor pitch and mode indicator.
(r) Rate of turn indicator.
(s) Radio direction finder.
(t) 12182 kHz homing on R.D.F.

Items (c–t) above subject to gross tonnage, keel laying date and arrangements of the vessel (See section II–1 on Page 30).

Radio:

(a) A V.H.F. radiotelephone.
(b) A source of power located in the upper part of the ship able to operate the V.H.F. for at least six hours.
(c) Radiotelephone installation able to transmit and receive on 2182 kHz, the radio telephone distress frequency.
(d) Radiotelegraph installation to be fitted with a Radiotelephone alarm signal generating device in addition to being provided with the facility to transmit and receive on 2182 kHz.
(e) On vessels of 500 GT or more but less than 1600 GT tons two qualified Radiotelephone operators to be carried if an operator is not carried to deal exclusively with Radiotelephone duties.

1983 Amendments to SOLAS 1974

Safety Equipment:

(a) Muster list and emergency instructions.
(b) Equipment operating instructions.
Instructions for manning survival craft and supervision.
(c) Training manuals.
(d) Onboard maintenance, operational readiness and inspection instructions to be available.
(e) One E.P.I.R.B. (emergency position indicating radio beacon) to be provided on each side of the vessel.
(f) At least three two way radio telephones to be provided.
(g) All lifejackets to be provided with a light.
(h) Immersion suits and thermal protective aids to be provided.
(i) Liferafts able to accommodate one hundred per cent of persons carried on the ship to be provided.
(j) A liferaft (for at least six persons) stowed forward of aft on ships where the "rule survival craft" are stowed in a position more than 100 metres from the stem or the stern.
(k) All life saving appliances to be provided with retro-reflective tape.

Radio:

See (e) and (f) above.

To Mr. D. H. Mann (Marspec):

PART 11-1 059

It is a requirement for the services mentioned to be provided with a readily accessible shut off located outside the space in which the services are located.

In the case of more than one machinery space it would be desirable to have separate facilities for each space so that possible 'black out' situations could be avoided. Should there be a 'black out' of the main power plant however the emergency arrangements would come into operation and supply illumination, emergency fire pumps etc.

It is difficult to specify an optimum number of remote stops but 50 would seem excessive. It is suggested a better arrangement would be to group them taking into account the equipment location in the machinery space. In the event therefore of a local fire the equipment in the locality can be switched off.

In any event should there be a major fire time is at a premium

and the equipment which may feed a fire is to be capable of being readily shut off.

PART 11-2 060

These batteries may be for all emergency power or transitional lighting as per reference. (Ch. 11-1/43, 44).

Lifeboats/Liferaft Launching Positions

There is to be effective emergency lighting at every lifeboat preparation station, muster and embarkation station and over the sides. If preparation and embarkation positions are one and the same this requirement may be met by one set of lights.

To Mr. J. H. Parry (HQ):

We would certainly agree that the time must come, when in order to improve the service to the Client, outports will issue the full term certificate on satisfactory completion, in all respects, of the renewal survey.

This will have a "Knock on" effect and reduce the work load both admin and technical required at subsequent ports of call to issue further short term certificates. We would also hope that the prospect of receipt of a full term certificate would encourage owners to complete the survey at one time, by ensuring that the ship is in a state of readiness for survey before arrival at the survey port.

The requirement that liferafts are able to be readily moved from one side of the ship to the other is generally understood to mean that the liferaft is of a mass of not more than 185 kg and is able to be moved from one side of the ship to the other at the same deck level without passing through a deckhouse. (The deckhouse might be on fire).

The procedure (on cargo ships) for conducting drills is very much an "in house" company procedure. It is however considered that regulation 18 of the revised CH. III of SOLAS covers the basic requirements.

Mr. Parry's custom for passenger ship lifeboat and equipment check is noted and provided a boat of each type has been satisfactorily surveyed would appear to be an acceptable practice. The subsequent renewal survey surveyor should however be fully aware of boats examined the previous year. This may present a problem if the survey is held at a different port. Suffice to say that the attending surveyor is to satisfy himself that all boats and equipment are in good and efficient condition.

For boat drills on passenger ships, full muster of crew to boat and liferaft stations is required. All personnel must be wearing lifejackets properly donned and secured. Random questioning of crew should ensure their familiarity with their required duties as shown on the muster list. Important junctions within the ship should be manned by crew members, wearing lifejackets, able to give detailed instructions and directions to passengers. As many boats as reasonable and practical should be swung out, lowered to the water and borne away.

Fire drills should be conducted in the engine room and in accommodation spaces in order to confirm the ability of the crew members concerned to efficiently operate all of the equipment provided and operate the necessary electrical isolating switches and ventilation dampers/shut downs.

The object of all drills is for the officers and crew to demonstrate to the full satisfaction of the surveyor, their awareness of the safety equipment and features available and their ability to use them efficiently and correctly.

To Messrs M. B. Christiansen and A. K. Almlundand (Amborg):

Tonnage

It is agreed that some confusion may exist concerning application of the use of the term "tons gross tonnage" as used in both the 1960 and 1974 SOLAS Conventions.

In the 1960 and 1974 SOLAS Conventions "tons gross tonnage" refers to the Gross as computed in accordance with National Regulations in force prior to the advent of the 1969 International Tonnage Convention, which came into effect on the 18th July, 1982.

Since the advent of the 1969 International Tonnage Convention however, in order to clarify the use of Gross Tonnage for SOLAS Convention purposes, it would have been advisable if the SOLAS Conventions had been modified so that in all places where the term "tons gross tonnage" appears in these Conventions, to delete the word "tons" and leave "gross tonnage" only.

The gross tonnage of a ship would then apply to the requirements of the SOLAS Conventions, where appropriate, irrespective of which tonnage regulations have been used in computing the gross tonnage.

PART 1-1 4 and 5

The authors consider that yet again this is some of the information which one day may well be recorded in the computer. If this ever occurs then rapid amendment will be possible as well as instant availability to most ports.

PART 1-1 14

It is a fact that the computer is set up to facilitate negative reporting of safety equipment and radio surveys. This means that at the present time, apart from the requirement to report to HQ certain basic data in the narrative area of the survey report, only items outstanding for completion of the survey are required to be reported (in association with the correct survey check list item number) in the area of the report headed "Check List Items Outstanding".

It should be noted that it is essential that items outstanding for completion of the survey are reported in the correct area of the report. This is because the computer will only present to third parties progressing a survey, outstanding items reported in the correct area of a report previously submitted.

The computer is not able (at the present time) to locate outstanding items incorrectly reported in the wrong area of a report, for example in the narrative area.

Updating of the Administrative Procedures Manual which will include revised requirements, amendments and clarifications, is at present being undertaken.

To Mr. G. Smart (Retired):

Your comments are much appreciated. An index is now included by popular request.

Separation of cargo ship and passenger requirements? It was a positive decision at the production stage not to separate the requirements, so we are afraid we are stuck with it for better or for worse, perhaps future authors will take note of your comments.

Whilst radio surveys in their entirety are always sub-contracted to fully qualified specialist radio engineers, the attending LR surveyor should always endeavour to satisfy himself the radio surveyor has fulfilled the requirements and properly conducted the survey. After all, the LR surveyor is required to counter-sign the survey report.

Your comments re the need for liferafts to be serviced by an agent approved by the liferaft manufacturer are most valid. Should a surveyor become aware that a raft has been serviced at a station which is not approved by the liferaft manufacturer, although the station itself may have been approved by the Authorities of the country in which it operates and/or other liferaft manufacturers, the possible disadvantages should immediately be brought to the attention of the owner or his representative.

INDEX

	Page No.	See Also
A		
Accommodation Ladders	33	ICL : 102
Amendments:-		
to SOLAS Signatories		ICL : 68
to SOLAS 1974 (1981 Amendments)		ICL : 125 & 111
to SOLAS 1974 (1981 Amendments: Fire Control Plan)		ICL : 128
to SOLAS 1974 (1981 Amendments: Greek Requirements)		ICL : 129
to SOLAS Ch IV Reg 7		ICL : 138
to SOLAS Ch III Reg 41.8/12 and 38.5.18 Food Rations		ICL : 139 (Liberia)
to SOLAS Ch II-2 Reg 45		ICL : 140 (Liberia)
to SOLAS (1983 Amendments) Lifejackets and Lifeboats		ICL : 195
Asbestos:- Use of on Panamanian flag vessels		ICL : 171
Amendments to Certificates of Registration and Statutory Certificates		ICL : 177 & 187
Annual or Docking Surveys: Check List		CIRC : 2373 & 2439
B		
BANGLADESH FLAG SHIPS: Statutory Surveys		ICL : 206
Beaufort (Australia) Inflatable Liferafts		ICL : 91
BELGIAN FLAG VESSELS: SOLAS Safety Equipment and Radio Surveys		ICL : 49
Bermudan Flag Vessels: Statutory Surveys		CIRC : 2318
Bilge Pumping Arrangements (Pass. Ships)	79	
Bulkhead Valves (Pass. Ships)	80	
Bouyant Apparatus (Pass. Ships)	78	
C		
Certificates:-		
Cargo Ship Short Term Issue of	5	
Cargo Ship Extension of	5	
Passenger Ship Safety Restricted Validity	5	
Passenger Ship Safety Extension of	6	
CO_2 Fixed Fire Smothering System: Periodical Survey of		CIRC : 2306
CO_2 Low Pressure bulk storage facilities in ships		CIRC : 2340
CO_2 Systems: Survey and testing on behalf of the Netherland Authorities		CIRC : 2387
CO_2 Systems: Survey of		ICL : 22
Fixed Fire Extinguishing Systems installed by INHAM B.V. of Dachealt		ICL : 79
Collision Prevention Regulations 1972		ICLs : 47 : 118 : 163
"COMET" hand held flares		ICL : 143
Computer based Reporting	6	
CYPRUS FLAG VESSELS		
A.R.P.A. Exemption		ICL : 217
Issue of Statutory Certificates		CIRC : 2327 & ICL : 32
Ratification of SOLAS 1974 and Protocol 1978		ICL : 157
Radiotelephony Radiotelegraphy Certificates		ICL : 204
Charts: Examination of		ICL : 189
D		
DANISH FLAG VESSELS		
Surveys and Certification		CIRC : 2382
Radio Renewal Surveys		ICL : 220
Davit Limit Switches		ICL : 101
Disposal of out of date pyrotechnics		ICL : 40
Distress signals (Pyrotechnics)	33	ICL : 165
Dry Powder Systems	55	
E		
Emergency Control/Special Arrangements in Mcy and Accommodation Spaces	56	
Emergency Electrical Power	56	
Emergency Position Indicating Radio Beacon (E.P.I.R.B.)	33	
Emergency Switchboard location of	56	
Emergency Fire Pumps		CIRC : 2418 (Superseding C2307)
Emergency Fire Pumps (transfer of class from other Societies)		CIRC : 2251
Equipment: Navigational: Performance standards		ICL : 133
Existing (PRIOR 1.9.84) inert gas systems		ICL : 124
Extension of:-		
SOLAS Certificates		CIRC : 2399
Safety Equipment Certificates on UK Flag Vessels		ICL : 80
Examination of Charts:-		ICL : 189
F		
FINNISH FLAG VESSELS SOLAS 1974/78		CIRC : 2403
Fire Appliances		CIRC : 2418
Fire Doors (Passenger Ships)	79	
Firemans Outfits (See also amendments 1 and 2)	52	ICL : 25
Fire Pumps in cargo ships		ICL : 141
Fire Protection Detection and Alarm System	56	
Fixed Fire Extinguishing and Protection Systems:-		
General Requirements	53	
CO_2 Systems	54	
Fixed Foam Systems	54	
Fixed Pressure Water Spray Systems	55	
Automatic Sprinkler Fire Detection and Alarm Systems	55	
Fixed Fire Detection Alarm Systems (Pass. Ships)	79	
G		
Galley Exhaust Protective System	56	
General Alarm	56	
GIBRALTAR FLAG VESSELS S.E. Certificates		ICL : 193
GREEK FLAG VESSELS:-		
Amendments (1981) to SOLAS 1974		ICL : 129
Portable Radio for Survival Craft		ICL : 60
Radio Surveys		ICL : 156 and 198
H		
HONG KONG FLAG VESSELS: Issue of Statutory Certificates under SOLAS 1974 and its 1978 Protocol		ICL : 164
Hoses and Nozzles	52	
Hydrants	52	
I		
Immersion Suits	50	
INDIAN FLAG SHIPS Statutory Surveys		ICL : 200
Inert Gas Systems	55	C2381
On new Chemical Tankers (Keel laid on or after 1.7.86)		ICL : 167
Existing (Installed before 1.9.84)		ICL : 124
Inflatable Liferafts stowage and securing arrangements		ICL : 191

International Share Connection 52
Intermediate Safety Equipment Surveys CIRC : 2374
ISLE OF MAN FLAG VESSELS:
Statutory Surveys ICL : 212
Italian Register: Mandatory Annual and Intermediate Surveys on behalf of CIRC : 2383

J

Jugoslav Register: Statutory Surveys on behalf of CIRC : 2368

K

KUWAIT FLAG VESSELS: Safety Equipment and Radio Surveys and Certificates CIRC : 2335
Language Requirements on various Instructions ICL : 196
Safety Equipment Surveys ICL : 201

L

LIBERIAN FLAG VESSELS
Amendments to SOLAS 1974 (1981 and 1983) ICL : 117 & 150
Amendments to SOLAS 1974 CH 11-2 Reg 46 ICL : 149
Amendments to SOLAS 1974 (1983) and Colregs 1972 Carriage of Additional Lifejackets ICL : 197
Certification with items outstanding ICL : 172
Consultation with B.M.A. ICL : 72
Foreign Bareboat Charter Registration ICL : 160 & 188
In laid-up status ICL : 107 & 119
Keel laying: Similar stage of construction ICL : 44
Life Saving Equipment and Waivers ICL : 48
Pyrotechnics ICL : 142
Safety Equipment Surveys
Examination of Charts ICL : 189
Safety Radiotelephony/ Radiotelegraphy Surveys CIRC : 2360
Short Term Statutory Certificates ICL : 90, 110 & CIRC : 2399
Statutory Surveys ICL : 174
Lifejackets 49
Lifejackets and Lifeboats (1983 A to SOLAS 1974) ICL : 195
Limit Switches on Davits ICL : 101
Liferaft securing arrangement: Ships registered in the Netherlands and Netherlands Antilles ICL : 73
Lifeboat Release Arrangements ICL : 179
Lifebuoys 49
Liferaft stowed forward ICL : 82
Line Throwing Appliance 33
Low Pressure Bulk Storage Facilities for CO_2 Fixed Fire Extinguishing Installations in Ships CIRC : 2340

M

MALTESE FLAG VESSELS: Issue of Statutory Certificates ICL : 76
Mandatory Annual Safety Equipment Surveys CIRC : 2374
MEXICAN FLAG VESSELS: Statutory Surveys and Certification ICL : 190

N

Navigational Aids:
Performance Standards 29
Requirements for 30
Suggested Operational Tests 30
Navigation Lights Requirements 31, 32
NETHERLANDS AND NETHERLANDS ANTILLES REGISTERED VESSELS:-
Less than 500 GROSS TONS: Safety Equipment Surveys ICL : 71
Liferaft Securing Arrangements ICL : 73
Plan Approval and Statutory Surveys of Cargo Ships ICL : 203
Statutory Surveys CIRC : 2376
Non Convention Safety Equipment and Radio Certificates CIRC : 2135
Norwegian Flag Vessels: Statutory Surveys on CIRC : 2420
Norwegian International Ship Register (NIS) ICL : 202, 211, 216

P

PANAMANIAN FLAG VESSELS:-
Amendments to Navigation Patente ICL : 145
Portable Radio Apparatus for use in Survival Craft ICL : 94
Short Term Certificates ICL : 90
Less than 500 GT Safety Equipment and Radio Certificates CIRC : 2390
Performance Standards: Navigational Equipment ICL : 133
PHILIPPINE FLAG VESSELS Radio Surveys ICL : 84
Pilot Hoist (Mechanical) 33
Pilot Ladders 32 ICL : 54 & 102
Portable Foam Applicator 52
Port State Inspections 6
Proforma Reporting 1981 and 1983 Amendments to SOLAS 1974 ICL : 170
Public Address System (Passenger Ships) 78
Pumps: Emergency Fire 51
Main 51
Protocol 1878 to SOLAS 1974 Safety Equipment Surveys CIRC : 2374

Q

"QUELL" Copper bodied fire extinguishers ICL : 85

R

Range Dates: Statutory Surveys ICL : 199
Record of Safety Equipment (SE1 5/87) ICL : 214
Renewal of SOLAS Convention Certificates CIRC : 2399
Reporting Safety Equipment and Radio Surveys ICL : 209
Rescue Boat:-
Equipment 48 & 49
Launching and Recovery Appliance 49
Engine 49
Retro Reflective Marking 50

S

Safety of Life at Sea Convention and Amendments (General)
SOLAS 1960 CIRC : 2211
SOLAS 1974 CIRC : 2361
SOLAS 1974 Application to Existing Ships ICL : 66 REV 1 & 66 REV 1 (ADD 1)
SOLAS 1974 Protocol 1978 CIRC : 2374
SOLAS 1974 Ch IV Reg Testing of the Two Tone Alarm Generating Device ICL : 168
SOLAS 1974 (1981 Amendments) ICL : 111
" ICL : 122
" ICL : 124
" ICL : 125
" ICL : 128
Ch IV Reg 7 one or two

Radio Officers ICL : 138
Ch II-2 Reg 45 (Liberia) ICL : 140
Solas 1974 (1983 Amendments) Ch III Reg 41.8.12 and 38.5.18 Food Rations ICL : 139
Solas 1974 (1983 Amendments) Ch III Reg 41.7.6 Lifeboat Releases Arrangement ICL : 179
Solas 1974 Protocol 78/1981 Amendments Ch II-2 Reg 60 Inert Gas Systems ICL : 147
Solas 1974/1981 and 1983 Amendments Proforma Reporting ICL : 170
Safety Equipment Surveys CIRC : 2305
Safety Equipment Surveys:-
Initial Surveys on Cargo Ships 4
Initial Surveys on Passenger Ships 4
On Existing Cargo Ships 4
On Existing Passenger Ships 4
Change of Flag on Existing Cargo Ships 5
Change of Flag on Existing Passenger Ships 5
Safety Equipment Surveys: Examination of Charts ICL : 189
Safety Equipment and Radio non convention certificates CIRC : 2135
Sand Boxes and Scoops 52
Short Term Safety Equipment and Radio Certificates ICL : 11 & 69
Short Term Certificates on Liberian Flag Vessels ICL : 110
SINGAPORE FLAG VESSELS:-
Compliance with Rule 38 of the Merchant Shipping (Prevention of Collisions at Sea) Regulations 1983 ICL : 151
Extension of Full Term Safety Equipment and Radio Certificates ICL : 137
Radio Ch IV SOLAS Reg 3 and 10 Equivalent Arrangements ICL : 109
Statutory Certificates and Survey Status ICL : 154
Updating Equipment 1981 Amendments to SOLAS 1974 Exclusions ICL : 137
Structural Fire Protection (Passenger Ships) 79
Sub Standard Ships CIRC : 2321
Surveys and Deficiencies (Outstanding items shown on Short Term Certificates) ICL : 83
Survey Reports and Associated Check Lists (SE and RT) ICL : 214
Survival Craft:-
Location of 33
Requirements for 34, 35, 36, 37, 38
GRP Lifeboats Survey Guidance Notes 39
Steel Lifeboats Survey Guidance Notes 40
Aluminium Lifeboats Survey Guidance Notes 40, 41
Launching Appliances 42, 43, ,, 78(P)
Simultaneous Release Mechanism 41, 42
Launching Appliances:- Survey of 44
Equipment (Lifeboats) 45, 46, ,, 78(P)
Lifeboats on Vessels with a Service Restriction 46
Equipment (Rigid Liferafts) 47, ,, 78(P)
Liferafts:-
Requirements for 47
Requirements at Survey 47
Marking of:- Rigid 47
Inflatable Liferaft Containers 48
Required Forward or Aft 48
Launching Appliances 48
Motorboats fitted with Radiotelegraph and Searchlight (Passenger Ships) 56(P)

T

Thermal Protective Aids 50
Two Way Radiotelephone Apparatus 33

U

UNITED KINGDOM FLAG VESSELS:-
Change of Name in Ports Abroad ICL : 126
Extension of Cargo Ship Safety Equipment Certificates ICL : 80
Radio Surveys and Certification CIRC : 2329

W

Water Fog Applicators (Passenger Ships) 78(P)
Watertight Bulkhead Doors (Passenger Ships) 80(P)
Up to and Inc ICD/ICL : 220 CIRC : 2439

Note: Surveyors should be aware of the need at all times to delete from and add to the above list as appropriate.

To Ulsan Surveyors:

New Construction

Lifeboats

Yes fire protected lifeboats must comply with Regs 41, 44, 45 and 46.

Regulations 45 and 46 are separated so that lifeboats fitted with a self contained air support system are required to be fitted with a fire protection system in order that they may survive the full scale fire test.

In practice and from experience to date most totally enclosed lifeboats destined to be fitted on Oil Tankers, Chemical Tankers and Gas Carriers are fitted with both an air support system and an external fire protection system.

Reg 26.1.6 and Reg 26.1.7 indicates that on Chemical Tankers and Gas Carriers carrying cargoes emitting toxic vapours or gases Lifeboats complying with Reg 45 (fitted with a self contained air support system) are to be fitted and, where such vessels and tankers are carrying cargoes with a flash point not exceeding 60°C, totally enclosed lifeboats fitted with a self contained air support system and fire protection MUST be fitted (Reg 46).

If such boats were not fitted at the building stage the capability of ships to lift certain cargoes in the future may be inhibited by the type of lifeboat fitted.

CO_2 portable fire extinguishers should not be accepted for use in totally enclosed lifeboats.

Lifeboat Davits

You clearly state the Convention requirement that lifeboats should be capable of being launched fully loaded from the stowed position to the water (See SOLAS CH III REG 28.1). This capability is one of the options which if complied with, enables the requirement to provide Immersion Suits/Thermal Protective Aids (other than those required to be provided as part of the boat equipment) to be dispensed with (See SOLAS CH III REG 27.3.2.1).

The decision to turn out the lifeboats ready for boarding from

a position other than the stowed position, must be an operational decision taken by the Master given the prevailing circumstances at the time.

It is our understanding that there is no requirement to fit bowsing tackles but neither is the use of such equipment expressly prohibited (see Reg 11.8).

The lifeboat embarkation requirement for new cargo ships is that they be boarded and launched directly to the water from the stowed position. Hence there is no need for bowsing tackles for compliance with SOLAS new cargo ship regulations. Passenger ship lifeboats may however require bowsing tackles if they are lowered to an embarkation deck for boarding.

Due consideration should be given to the strength of the securing points on the lifeboat.

Your point made with respect to the brake control wire within the lifeboat should be noted by all Surveyors.

It is agreed that it is impracticable to heel a vessel 20° for the purpose of testing the lifeboat davits. However, this is simulated during the prototype testing, in order to verify the strength of the rig and the efficiency of the system in this condition.

The lower right column of Page 44 of the paper describes an acceptable method of testing on board the ability of the davit/boat to turn out and lower against an adverse 20 degree list.

The effects on davits of heel angles in excess of 20° for oil tankers, gas and chemical carriers need only be considered in the low-side-list condition, where it is assumed that clearance with the vessels side will be no problem.

Nevertheless it is still to be demonstrated that the davits are structurally adequate for operating at heel angles in excess of 20° and consequently where it is known that a particular davit is to be fitted to either tankers, gas or chemical carriers it is recommended that simulation of the larger heel angles is included in the prototype testing. If the final heel angle in the damaged state is not known at the time of prototype testing then it is suggested that an angle of 30° is simulated to cover all possible eventualities.

Alternatively the davits may have to be removed after installation to enable adequate testing at the final heel angle to take place.

Manropes

The facility to indicate this requirement complied with, was provided with partially enclosed lifeboats and open lifeboats fitted on existing ships in mind.

With hindsight it would perhaps have been better omitted from the revised SE1 and where necessary (along with items of equipment previously required in open lifeboats but no longer required in totally enclosed lifeboats) hope that such equipment/facilities would be reported on page 21 of the revised record when it is used to report surveys on EXISTING SHIPS. See also reply to Mr Wong.

Survival and Training Manuals

These are very much a matter of concern for the Owner/Master, with respect to the amount of information provided in any one section. They are generally speaking unique to the ship with often only the company requirements related to Mustering and Fire and Abandon Ship drills common throughout the company fleet.

Providing the Manuals, contain requirements, which cover the requirements of REGS 51, 52 and 53 of CH III they should be accepted by the Surveyor. (See Also ICD/ICL 170 Para 4.2.5).

Navigation Lights

The "uniform interpretation" for the height of the Foremast light above the Upper Deck is contained in the 1972 Regulations for the Prevention of Collisions at Sea [See Annex 1.2(a)(i)]

Signalling Apparatus

Your comments are noted with some sympathy. However the present requirements are as contained in the above mentioned regulations.

As you are well aware mechanical equipment is subject to failure.

Firemens Outfits/Foam Tanks Use with Portable Applicators

The protection afforded by rubber boots from possible electrical hazards is considered to outweigh the possibility of the boots disintegrating.

A firefighter would normally be in the company of a back-up man, who if necessary could ensure he was protected by a curtain of water around his feet.

The plastic foam tanks are for use with portable applicators and, being much lighter than similar metal tanks, are able to be more easily handled with the portable applicators.

EXISTING SHIPS

Surveys

The pressure on outport Surveyors to conduct thorough surveys in shorter periods of time, brought about by the ever increasing number of Port State Inspections and the modern trading patterns of ships is fully appreciated.

The time taken to carry out a satisfactory survey is as most of our colleagues are well aware a function of a number of factors such as; the type of ship, how well it is prepared and ready for survey, the availability, capability, and willingness of the crew to participate in the rapid and satisfactory completion of the survey etc.

It must never be forgotten that the CLASS Surveyor attends, the vessel for STATUTORY SURVEY at the request of the OWNER on behalf of the FLAG STATE to ensure that the vessel is in compliance with INTERNATIONALLY AGREED requirements applied by the FLAG STATE and with which the OWNER has undertaken to comply.

For annual or intermediate surveys, in theory, the attending Surveyor should be able to confirm that all the required equipment is on board and well maintained and that the drills and tests required to be held at regular intervals by the Master and Crew under the requirements of the Convention, have in fact been held.

In practice it is not always as simple as that. Should the attending Surveyor be less than satisfied with what he sees or with the results of the tests, further testing as deemed necessary should be carried out.

It is considered possible to complete a satisfactory Renewal Safety Equipment Survey on a 30,000 Ton Products Carrier within one day, providing the ship is well prepared for survey and a willing and competent crew are available to help.

Dividing the Survey between deck and engine room is of great assistance where the office work load enables two Surveyors to attend.

A similar survey conducted on a vessel which is not well prepared and without enthusiastic support from the available crew members and on which the equipment is in poor condition may take as much as five times longer.

It should be remembered that visits to sight repairs etc may be charged additional to the scale fee where the service rendered is considered to be in excess of the norm.

Liferaft Servicing

Liferaft manufacturers publish lists of approved service stations and it must be the responsibility of the Master to endeavour to ensure that the liferafts fitted on his ship are serviced at stations approved by the manufacturer.

(See also the reply to Mr. Smart).

Emergency Steering Position

Has been defined as a position other than the normal steering position on the Bridge from which it is possible to control the rudder in an emergency.

Heading information on NEW SHIPS is required to be provided by a Gyro Compass or a Magnetic or Gyro Compass repeater.

On EXISTING SHIPS a Magnetic or Gyro Compass repeater or a portable magnetic compass is acceptable.

Reports

Please refer to the replies to MR. SMITH and MESSRS ALMLUND and CHRISTIANSEN.

To Bremerhaven Surveyors

It is the opinion of the authors that the use of oil lanterns only is not prohibited by the 1972 Regulations for the Prevention of Collisions at Sea.

It would however appear to be impracticable to provide only oil lanterns in many instances. For example on ships where the use of such lights would be prohibited should certain cargoes be lifted, or where the use of such lights would not be permitted in certain areas of some ports by the harbour authorities.

As you state Annex I, II refers to the intensity of non electric lights and it is our opinion that provided such lights are certified for compliance with the technical requirements of the 1972 Regulations they should be accepted.

If only single electric lights are fitted they are required to be able to be powered from the emergency source of electrical power (see SOLAS CH II-1 Reg. 43.2.3). Additionally a spare set of bulbs should always be carried and a space is provided on the revised SE1 5/87 item 2.5.15 to record this provision.

The problem of a power supply failure can be overcome by switching from one source to another and a bulb failure overcome by a simple change. The difficulty in complying with Rule 20(B) and (C) in bad weather with respect to a masthead light bulb change is all too obvious. The usual modern day solution is to fit two tier steaming lights (masthead, side and stern) with one set powered from the main source of electrical supply and the other able to be powered from the emergency source. It should be noted that neither SOLAS nor the 1972 Regulations for the Prevention of Collisions at Sea require that two sets of lights be provided, but simply that the required lights be displayed from sunset to sunrise and from sunrise to sunset in bad weather. (See also ICD/ICL No. 118).

In the opinion of the authors you are correct when you suggest that single electric lights backed up by oil lights certified for compliance with the regulations would satisfy the requirements of the regulations, of course due account should at all times be taken of any known national requirements before such an arrangement is approved or accepted.

For the reasons outlined above such an arrangement should be considered less than ideal.

We would also ask are there many lamp trimmers still sailing the Oceans of the World?

Neither the Rules nor SOLAS require double wiring from the navigation lights to the distribution board.

As an interim measure to comply with the new Col regs, some National Authorities permitted existing navigation lights to be fed by a second supply via a change-over switch located at a position at the main deck level near the navigation light.

The navigation lightboard is to be fed from the emergency source of power. Provision is also to be made for navigation lights to be powered via an alternative circuit which may be supplied from the main switchboard.

To Mr. J. J. Stansfield (Gdansk):

With respect to the layout of the paper, this was a policy decision taken after much discussion, please see also reply to MR. SMART. The appendices deliberately include extracts from the Holland, Magill paper among others.

It is considered that inclusion of such data is to the benefit of the paper which is intended as a "ready-use" onboard reference document for the outport surveyor. The inclusion of relevant information from other sources was therefore felt beneficial.

Navigation Light Positions

Some vessels do in fact have EXEMPTIONS from compliance with certain of the requirements of the regulations granted by the flag state administration.

It was considered worthwhile to provide a facility to record such a situation for the benefit of surveyors dealing with subsequent surveys. A "No" answer to the question should alert the surveyor to the need to locate the appropriate EXEMPTION certificate.

The Number of Lifeboats

Is considered more convenient to provide the facility to record the details of at least four lifeboats than it would have been to provide space for recording the details of only two.

Efficient Fog Horn

Is considered to be the ship's whistle.

Accommodation Ladders

Are considered to be surveyable items at Safety Equipment Surveys when they form part of the Pilot boarding arrangement i.e. when in any condition of the ship the Pilot is required to travel vertically more than 9 metres (See ICD/ICL 102), and the accommodation ladder is used in association with the conventional Pilot Ladder [See SOLAS CH V Reg 17(a)(ii)].

Freefall Lifeboats

At the present time the Convention makes no difference between types of lifeboats fitted when considering the drills required to be held. (See CH III REG 18).

The requirement is "that each lifeboat shall be launched with its assigned operating crew aboard and manoeuvred in the water at least once every 3 months.

It is considered that this is an area where the attending Surveyor should use his initiative and take due account of the conditions of the lifeboat and its launching and recovery appliance as presented for survey, log book entries and the depth of water under the keel of the ship. It should not be overlooked that freefall lifeboats are required to be able to be recovered using a winch and falls. If considered necessary they can be launched using the winch and falls.

Surveyors should also exercise extreme care in testing any onboard equipment the operation of which should always be left to the ships staff. The paper makes this point re testing of navigational equipment etc.

A weak link would be required for each liferaft in a multi storage system. For davit launched liferafts the weak link of each raft will require disconnection before attachment to the davit fall, the painter however should be attached to the ship's structure before the raft is turned out for inflation and boarding.

Liferaft for Training Purposes

It is agreed that where possible, a davit launched inflatable liferaft should be provided for training purposes on ships where such liferafts are fitted.

The Raft/Container should be clearly marked to indicate its purpose and that it does not form part of the L.S.A. required to be provided under the terms of the SOLAS Convention.

In 053 a list of spaces protected by the sprinkler installation would be expected e.g. "all accommodation and service spaces decks 8, 9, 10". Under the column "Location of stop valves" a

list of sprinkler stations is expected e.g. "Deck 8 Frame 65(P).

It was not considered necessary to mention draught stops as these are numerous and built into the ship. They should of course be examined along with structural fire protection during the course of survey. Similarly passenger ships have a large number of ventilation dampers, too numerous to indicate on a report but easily located from the fire control plan. Swimming pool dumping arrangements would also be indicated on the damage control plan and referred to in the "Instructions to Master" should the contents of the pool require dumping in order to improve stability after damage.

The duplicate sets of fire plans should be located at the normal embarkation/disembarkation point for passengers going ashore.

Future Developments

The Marine Escape Slide is here to stay and the Authors would anticipate increased use of this equipment on for example Passenger Ferries which operate on relatively short routes.

We would have reservations with respect to it's use on large ocean going passenger vessels, if only from the need to fit sufficient units to account for the possibility of a unit failing to operate correctly or not being tenable. Notwithstanding the thoughts of the authors, it is understood one major Administration has approved MES for use on Passenger Ships on unrestricted service.

Global Maritime Distress and Safety System

Please see the reply to Mr. Smith.

The authors would anticipate a period of consolidation of the present regulations related to safety with only relatively minor amendments rather than significant new requirements being introduced.

We foresee the time when perhaps we have an "all" embracing Safety Certificate for cargo vessels with perhaps a five year life cycle with the ship required to undergo annual inspections for Safety Equipment Radio, Load Line and Safcon which if satisfactory would enable the certificate to be endorsed and continue to be valid.

Perhaps as the "five year" (if that is what it turns out to be) life of the certificate draws to an end the Owner may be given credit on the succeeding certificate in respect of a Renewal survey held early with the possibility that a Renewal Survey held "late" will be "back dated" to due date of the Renewal Survey.

Only time and I.M.O. will tell us.

Corrigenda:

Page 36	Top Sketch 1948. The arrow linking the text relating to motor lifeboat or mechanically propelled lifeboat, should of course be to the boat shown on the port side of the ship.
Page 100	"Actual Provisi" should read "Actual Provision".

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Lloyd's Register Technical Association

INSPECTION OF NUCLEAR INSTALLATIONS

Two Papers

by

G. S. Scoones and R. Porter

Paper No. 4 Session 1987–88

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Written contributions to the discussion of this paper are invited from members of the Lloyd's Register Technical Association. To ensure inclusion in the discussion paper, the contributions should be received by the Hon. Secretary in London not later than the 30th April, 1988.

Hon. Sec. R. V. Pomeroy
71 Fenchurch Street, London EC3M 4BS

THE ROLE OF THE INDEPENDENT INSPECTION AUTHORITY

by
G. S. Scoones



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TABLE OF CONTENTS

1. INTRODUCTION
2. DESIGN CODES
3. REGULATORY AUTHORITIES
   - 3.1 U.K. Requirements
   - 3.2 U.S.A. Requirements
4. QUALITY ASSURANCE
   - 4.1 U.K. Practice
   - 4.2 Quality Plans
   - 4.3 Quality Assurance Programmes
   - 4.4 U.S.A. Practice
5. INSPECTION
   - 5.1 Manufacturing Faults
6. SIZEWELL B
   - 6.1 Administration Requirements
   - 6.2 Ultrasonic Inspection
   - 6.3 Code Inspections
   - 6.4 Sizewell B Pressure Vessel
   - 6.5 Materials
   - 6.6 Weld Procedure Testing
   - 6.7 Certification
7. IN-SERVICE INSPECTION
   - 7.1 U.S.A. Requirements
   - 7.2 U.K. Practice
   - 7.3 Magnox Reactors
   - 7.4 A.G.R.s
   - 7.5 P.W.R.s
8. CONCLUSIONS
9. REFERENCES

APPENDICES

1. INTRODUCTION

Lloyd's Register Industrial Services has undertaken design assessment and examination of primary circuits and reactor pressure vessels of nuclear power plants since the early 1950's. The first reactors built in the United Kingdom were built under L.R. survey for the United Kingdom Atomic Energy Authority (UKAEA) at Calder Hall, Cumberland and Chapelcross (Scotland).

The reactors were commissioned in 1956 and since then LRIS has continued its involvement with these plants by in-service inspection and membership of the Pressure Vessel Periodic Inspection Committee (PVPIC), this committee meets annually to discuss all aspects of safety of the pressure circuits. The items subject to direct in-service inspections are the gas ducts, bellows and heat exchangers. The reactor pressure vessels are examined by remote inspection techniques.

The first commercial nuclear power stations built in the United Kingdom were commissioned by the Central Electricity Generating Board (CEGB) in 1962 at Berkeley (Gloucestershire) and at Bradwell (Essex). These CO_2 cooled Magnox reactors which were built under LRIS survey were based upon the successful UKAEA reactors at Calder Hall and Chapelcross. Our close association with the CEGB and the Magnox type reactors continued with inspection services being provided for Sizewell 'A', commissioned in 1966, and Hunterston 'A' (Fig. 1) commissioned by the South of Scotland Electricity Board (SSEB) in 1964.

In all 26 Magnox-type reactors were built in the United Kingdom for the UKAEA, CEGB and SSEB. Of these LRIS provided inspection services for 16 with 2 for export to Tokai Mura (Japan) and Latina (Italy). The Tokai Mura and Latina reactors were based upon the design developed for Bradwell.

During the period between the commissioning of Calder Hall, the first station in the world to feed electricity from nuclear energy into the national grid, to the last Magnox station commissioned at Wylfa (Anglesey) in 1971, the unit capacity rose from 200 megawatts of electricity (MWe) to 840 MWe.

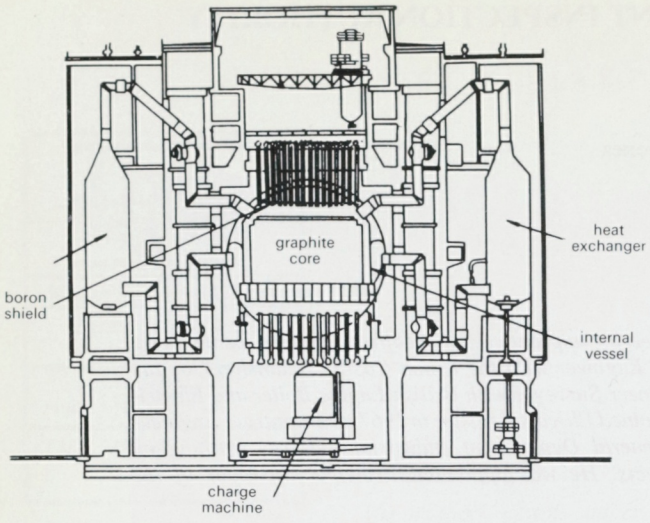


Fig. 1 Hunferston A Magnox Reactor

The reactor system adopted for the U.K. second nuclear power programme was based on the prototype Advanced Gas Cooled Reactor (AGR) built for the UKAEA at Windscale (Cumbria). Enriched uranium enabled a uranium dioxide fuel contained in stainless steel cans to be used capable of operating at higher temperatures than in the Magnox reactors. This in turn allowed the use of enhanced steam conditions.

In 1968 LRIS was asked by the CEGB to provide design and inspection services for the board's first AGR at Hinkley Point 'B' (Somerset) (Fig. 2) and later for the station at Heysham II (Lancashire) where construction started in 1980. The Hinkley Point 'B' reactors were commissioned in 1976, the twin reactors having a combined capability of 1320 MWe. The Heysham II reactors are nearing completion and have a similar power capability.

A summary of U.K. nuclear power stations built under the Society's survey is shown in Table 1.

2. DESIGN CODES

In the early days of the United Kingdom nuclear power programme the reactor pressure vessels and primary circuit components were designed and constructed to the best codes of practice of the day, manufactured to a high standard and inspected using the best known techniques of radiography and crack detection. Ultrasonic examinations were performed in the early 1950's for the purpose of detecting laminations in plate material.

The pressure vessel standards available at the time were BS 1500[1] and the Rules of Lloyd's Register for Class 1 pressure vessels. These and other requirements formed the basic specification for the pressure vessels and pressure containing circuits.

In 1957 notes were prepared by the Land Division of the Society giving recommendations for the design and construction of the primary circuit pressure components of land based nuclear power plants of the type then to be built in the United Kingdom. As a result of experience gained these notes were amended and in 1960 Rules covering materials, design and inspection requirements [2] were issued.

A similar situation existed in the United States of America where during the mid 1950's the first Pressurised Water Reactors (PWR's) were built. The existing ASME Pressure Vessel Code [3] did not specifically cover pressure vessels that were an integral part of nuclear installations. It therefore became necessary for the ASME Committee to apply its already established system of "code cases" to nuclear vessels. As a result Code Cases

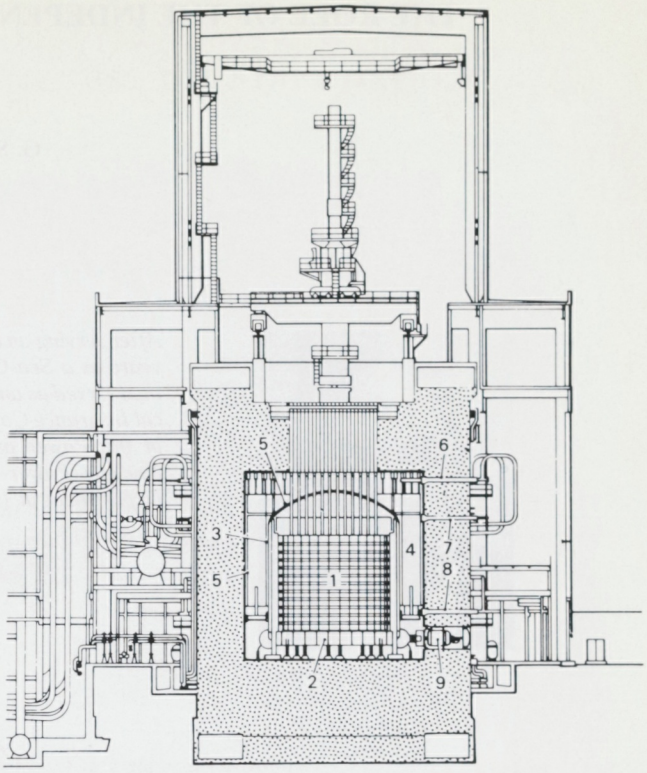


Fig. 2 Hinkley Point B AGR

1270N for nuclear vessels and 1272N for containment vessels were issued. Additional requirements for full radiography of all welded seams and stress relieving in all thicknesses were consolidated in Code Case 1270N. Any exemption from stress relieving of Containment Vessels, (Code Case 1272N) was given only if certain requirements were met in respect of notch ductility of the materials, and for materials in thickness up to $1\frac{1}{2}$ inches providing a pre-heat temperature of 100°C was used during welding.

These codes provided assurance against tensile failure as a result of internal and external pressures and the stresses imposed on the pressure shell boundary by concentrated loads from the supports and internal fixtures. Non-ductile failure was covered by using materials with good low-temperature V notch properties and by ensuring that the welded structure was post weld heat treated. The design strength values used were appropriate to a factor of safety of 4 on the ultimate strength of the material. Welded joints to BS 1500: 1949 and the subsequent revised edition of 1958 were rated lower than a seamless shell which was given the highest value of 1. Changes in the type of joint, weldability of the material, omission of stress relief, reduced radiography and limited mechanical tests and inspection all reduced the joint factors by a series of discounts. Although none of these factors was applicable to reactor vessels built to these codes, the maximum joint efficiency that could be used under any set of circumstances was 0.95.

At the time the 1958 edition of BS 1500 part 1 was published it was recognised by the British Standards Institution that whilst the design and construction of nuclear pressure vessels was based upon BS 1500 a considerable number of additional requirements covering design, inspection and testing has been imposed on manufacturers by the owner's specifications. It was therefore decided to prepare a standard specifically for use on nuclear power plants and in 1965 BS 3915[4] was issued. This

TABLE 1
U.K. Nuclear Reactor Plants.
built under Lloyd's Register survey.

PLANT	REACTORS		CONSTRUCTION STARTED	COMMISSIONED	REACTOR COOLANT		THERMAL OUTPUT MW(t)	STEAM AT TURBINES		ELECTRICAL DESIGN OUTPUT (GROSS) MW(e)
	TYPE	NO			PRESSURE PSIG	TEMPERATURE °C		PRESSURE PSIG	TEMPERATURE °C	
CALDERHALL	MAGNOX	4	1953	1956	100	345	1080	220	321	240
CHAPELCROSS	MAGNOX	4	1955	1959	100	345	1060	220	329	240
BERKELEY	MAGNOX	2	1957	1962	140	350	1170	310	320	334
BRADWELL	MAGNOX	2	1957	1962	147	360	1000	765	371	347
HUNTERSTON A	MAGNOX	2	1957	1964	150	380	640	515	369	388
SIZEWELL A	MAGNOX	2	1961	1965	278	360	1600	646	387	650
HINKLEY POINT 'B'	AGR	2	1967	1976	615	634	2988	2315	538	1320
HEYSHAM II	AGR	2	1980	1980	630	635	3110	2315	538	1320
SIZEWELL B	PWR	1	1987	–	2296	325	3411	966	282	1110

standard was developed to reflect the needs of the industry and was one of the referenced documents in the design specification for the Hinkley Point 'B' AGR which was built under survey.

The standard included requirements for a basic design check of membrane stress against permissible code stress and a final design appraisal using analytical methods to assess structural integrity against modes of failure such as excessive deformation and elastic instability, due to high compressive or bending loads, and fatigue damage. Welded joint efficiences used in the basic design check were still retained at 0.95 for Category 'A' vessels, Category 'A' vessels being defined as "Pressure Vessels and components which are intended to contain radioactive materials and are subject to neutron irradiation such that the physical properties of the materials of construction may be affected during the projected life of the nuclear installations of those which, from biological considerations of radioactivity, will be inaccessible for comprehensive periodic examination and maintenance".

The nominal design stress used in BS3915 for the BS 1501 series of plates [5] and for other materials not specially listed in the code, was based on the lowest of the following criteria:

Minimum UTS at room temperature 2.7
or *Minimum Yield at design temperature* 1.5
or *Stress to Rupture in 100,000 hours* 1.6

In 1963 the American Society of Mechanical Engineers published its first rules for materials, fabrication, inspection, testing and certification of vessels for use on nuclear power plants. These rules were adopted as Section III of the A.S.M.E. Boiler and Pressure Vessel Code.[6] The classification of pressure vessels was broadly similar to previous requirements, reactor pressure vessels being defined as Class A components and containment vessels as Class B components.

The design criteria of Section III represented a significant departure from conventional practice in so much that they required structural integrity of nuclear pressure vessels to be assessed by analytical methods as opposed to code calculations which determined preliminary scantlings of shells and ends in relation to pressure and temperature conditions. However, the maximum allowable stress values were those given in Section VIII of the code which were still based on one quarter of the ultimate tensile strength.

Whilst the "Provisional" requirements issued by the Society were amongst the first survey rules to be published, the ever increasing developments that were taking place in the nuclear industry would have required extensive and frequent revisions to be made and would have duplicated the work being done elsewhere in the British and American standards institutions. As a result the Society rules were not developed beyond the original issue.

3. REGULATORY AUTHORITIES

3.1 U.K. requirements

In the United Kingdom the main legislation governing the safety of nuclear installations is the Health and Safety at Work Act 1974 and the associated relevant statutory provisions of the Nuclear Installations Act 1965.

Under these Acts no site may be used for the purpose of installing or operating any commercial nuclear station unless a nuclear site licence has been granted to the corporate body by the Health and Safety Executive. H.M. Nuclear Installations Inspectorate (NII) is that part of the Health and Safety Executive responsible for administering this licencing function.

In the U.K. the corporate bodies operating civil nuclear reactors are the UKAEA, BNFL, CEGB and SSEB and it is their responsibility as licence applicants to present to the NII a safety case sufficiently detailed to ensure that all safety criteria are met.

The NII do not issue codes or standards for nuclear plant and each safety case is assessed against the applicants design safety criteria much of which has been developed by the corporate bodies in consultation with the NII over the years. These safety criteria may make reference to BSI or ASME specifications.

Included in the safety submission is the requirement for the licence applicant to identify the arrangements made for the inspection and testing of certain materials and items of plant. These items of plant include the pressure retaining parts of the reactor together with supports and internal parts and the pressure circuit and its associated components. All material related to the above components should, by examination and testing, be shown to be entirely suitable for their intended use and full and accurate records of these examinations and tests are required to be kept.

To satisfy these requirements it was customary on the Magnox and AGR plants for the CEGB and SSEB to employ a member organisation of the Nuclear Inspection Authorities (Joint) Advisory Committee. This committee was founded by members of the Associated Engineering Insurers (A.O.T.C), Lloyd's Register and the CEGB. Inspection schedules as shown in Appendix 1 are formulated for each item of reactor plant showing the inspection and tests to be performed by the inspection authority and the participation in design assessments and the inclusion of these schedules in the inspection contract assured the boards that the NII requirements for examination and testing of materials and certain plant would be met.

Quality Assurance has in recent years become an additional licence condition. The applicant has to specify to the NII for its approval his quality assurance programme and management scheme together with the Q.A. schemes for the main contractors and sub-contractors, for the main safety related components. These quality arrangements are related to matters which could affect the safe operation or safe condition of the plant and cover the design, construction, commissioning and operation.

3.2 U.S.A. requirements

In the USA a licence to construct and operate nuclear power plant is issued by the Director of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission (NRC). The applicant is required to submit to the NRC preliminary and final safety analyses including a safety assessment of the site, plant design criteria, reactor and component design, coolant systems, reactor protection systems, coolant boundary and containment.

The complete NRC requirements for siting and operating nuclear power plants are listed in the Code of Federal Regulations 10CFR50. The quality assurance requirements are stated in Appendix B of that code.

4. QUALITY ASSURANCE

4.1 U.K. practice

For the safe and continued operation of pressure vessels the designer and fabricator have to produce components that are suitable for the containment of pressure at the intended operating temperatures and for the retention of dimensional stability under all specified loads. For non nuclear vessels the internal and external parts of vessels can be made accessible to permit thorough examinations to be made. These examinations are performed at statutory intervals thus ensuring the condition of the plant is known and regularly monitored.

In some areas of nuclear plant, accessibility and the environment do permit external and internal examinations to be made e.g. the gas ducting and heat exchangers of Magnox plant and areas behind the biological shield of advanced gas cooled reactors. These examinations are performed by personnel wearing protective clothing and in some cases (AGR) fully air cooled suits, movements are restricted and the time of entry restricted dependant upon the radiation levels.

The performance of pressure parts in service is also dependant on good design, the right choice of materials and fabrication and inspection techniques, good workmanship and in-service inspection. The design life of nuclear plant is upwards of 30 years and because many parts are inaccessible for in service inspection it is of the utmost importance that the methods for design, procurement, fabrication inspection and testing are properly documented and managed.

The implementation of formal quality assurance in the U.K. nuclear programme came in 1980 at the commencement of the Heysham II and Torness projects, prior to this the arrangements made by the corporate bodies to employ an Independent Inspecting Authority (IIA) to carry out inspections of materials and certain plant satisfied the existing NII licence requirements.

The quality assurance arrangements used on the Heysham II & Torness project were based on the requirements of the National Nuclear Corporation (NNC) specification G/7622 and were arranged on a hierarchical basis between the purchaser and contractor. Thus, the contractor was responsible to the purchaser and the material supplier responsible to the contractor, between each there were agreed QA arrangements which were described in the quality assurance programmes and quality plans. After the start of the Heysham II project, British Standard BS 5882[7] was published. This specification is the basis for the quality assurance arrangements made for Sizewell 'B'.

A variety of designations or symbols has been used to describe the type of inspection that is intended to be performed against a quality plan activity; W1 and W2 has implied 100% and sample witness; 10% W1 W2 represents 100% inspection of the first 10% of components and thereafter, if satisfactory, the level of inspection will be reduced to a sample witness. The ASME codes and hence Sizewell 'B' requirements require inspection and test and process activities to be marked up on the plan using the notation of 'H' representing Hold points. Hence the inspector will stipulate the inspection he intends to make by marking the plan with an 'H'. Use is also made of Notification points 'N'.

The difference between a 'Hold' and a 'Notification' point is the time at which the manufacturer will hold production after having notified all parties that the item is ready for inspection. A Notification, 'N', point means that arrangements should be made to witness the activity; it does not mean that inspection can be waived.

The quality assurance arrangements made for Sizewell 'B' are similar to those which existed on the Heysham II project whereby each contractor applies to his procurement activities the hierarchial principles of quality assurance in which the procurement controls necessary to assure the quality of an item are applied throughout.

The QA requirements are based BS.5882: 1980, lower levels of control on items and services which differ in regard to relative safety, reliability and performance importance is permitted by BS 5882 but the responsibility of approval of such arrangements rests with the CEGB.

For some procurement action it may not be appropriate to specify the full quality assurance arrangements required by the above. Examples of such cases are material purchased from stockists whereby the material is approved by sample check tests or machining of components where maintenance of material identity can be shown to be controlled. In these cases the purchaser identifies all operations and inspection activities on quality plans which are subject to approval.

L.R.I.S. participates with the CEGB in its audits of main and sub-contractors and monitors the quality assurance activities of the firms as part of its inspection responsibilities.

4.2 Quality Plans

The concept of quality plans and their applications are not new, they were however, first introduced into the U.K. nuclear industry on a formal basis at the start of the Heysham II and Torness contract. A quality plan, shown in Appendix II, is a document setting out specific quality practices and procedures relevant to a component or system. They are used to describe the manufacturing and construction sequences and reference the

inspection test and certification procedures necessary for the supply of materials and component fabrication. Each inspection activity and its location in the production sequence is marked in the quality plan by the manufacturer. The inspection authority marks up the plan indicating their requirements for witnessing the inspections and tests. It is important that quality plans are subject to an update during the fabrication period to reflect any change in the manufacturing sequence, inspection and testing activities. During manufacture the quality plans or related schedules are used as an inspection check list. These have to be signed off by the IIA when satisfied that the operation for which they have a marked up activity has been satisfactorily completed.

4.3 Quality Assurance Programmes

For projects requiring formal quality assurance the following documents are typical of the Lloyd's Register quality programme:-

L.R.I.S. Quality Manual
L.R.I.S. Procedures Manual
Guidance Notes
Interface documents
L.R.I.S. Departmental procedures.

The interface documents generally take the form of memoranda which provide the means of co-ordination between I.S. and the various internal departments such as Advanced Engineering Services and N.D.E. The documentation describes the specific contract requirement and any administration requirement which is different to our normal procedures.

Not all of the quality assurance requirements specified in national or project standards are applicable to normal IIA activities. The procurement, manufacturing control, handling, storage and shipping activities are essentially manufacturing operations and applicable only to the manufacturer. It is therefore necessary at the start of a contract to define and agree with the client those IIA activities for which quality procedures will be written. Compliance with these procedures by the local Surveyors is then subject to regular internal and external audit at Head Office and the local office levels.

4.4 U.S.A. Practice

Formal Quality Assurance requirements were first introduced in the ASME Section III code in 1972. These requirements were based on the 18 criteria of Appendix B of 10 CFR 50 which required the manufacturer of specific nuclear components to establish and document controlled manufacturing procedures and quality assurance programmes.

Before certificates of authorisation to construct Class 1, 2 and metal containment (MC) components, are issued by ASME to a manufacturer in the U.S.A. the ASME have to evaluate and accept the manufacturer's quality assurance programme and the implementation of its procedures. The continued effectiveness of the manufacturer's quality activities are then monitored by the authorised inspector during fabrication and by the ASME audit team at each triennial renewal of the certificate of authorisation.

The authorised inspector is qualified by examination as prescribed under the rules of any state or municipality which adopts Section III of the Code. It is necessary for him to be regularly employed as a state, municipal or insurance company inspector. L.R.I.S. Insurance Inc. is an Authorised Inspection Agency and employs such authorised inspectors and supervisors.

The construction, testing and inspection of nuclear power plant in the years before the formal introduction of quality assurance was carried out to accredited design codes, previous engineering experience and written specifications for materials, fabrication and testing. The successful operation of many of these plants suggests the fundamental principles of quality assurance were already known and practised prior to the introduction of the current Q.A. Standards.

5. INSPECTION

Pemberton and Crossley[8] identified the need for high standards of construction and inspection of nuclear components. They also recognised that the main construction problems presented by reactor pressure vessels were associated with the large size and also site fabrication.

At the start of the Heysham II/Torness AGR projects the declared policy was to manufacture as many of the components as possible within the factory. Large items of plant such as the gas baffle Fig. 3 and liner roof assembly Fig. 4 weighing 1000 tons each were entirely shop manufactured and transported by barge from Teeside to the respective sites in England and Scotland. The liner wall assembly Fig. 5 was site erected from shop fabricated panels.

The function of the AGR Gas Baffle which is a high integrity vessel is to separate the circulating gas at reactor inlet pressure from the gas at reactor outlet pressure thus determining gas flow around the primary circuit. The gas baffle also has to maintain its position relative to the core and to the roof standpipes so that the passage of the fuel stringers and control rods in and out of the reactor is not impeded.

The gas baffle is a cylindrical structure 13.85 metres diameter with a tori-spherical shape dome. The dome thickness is 67mm

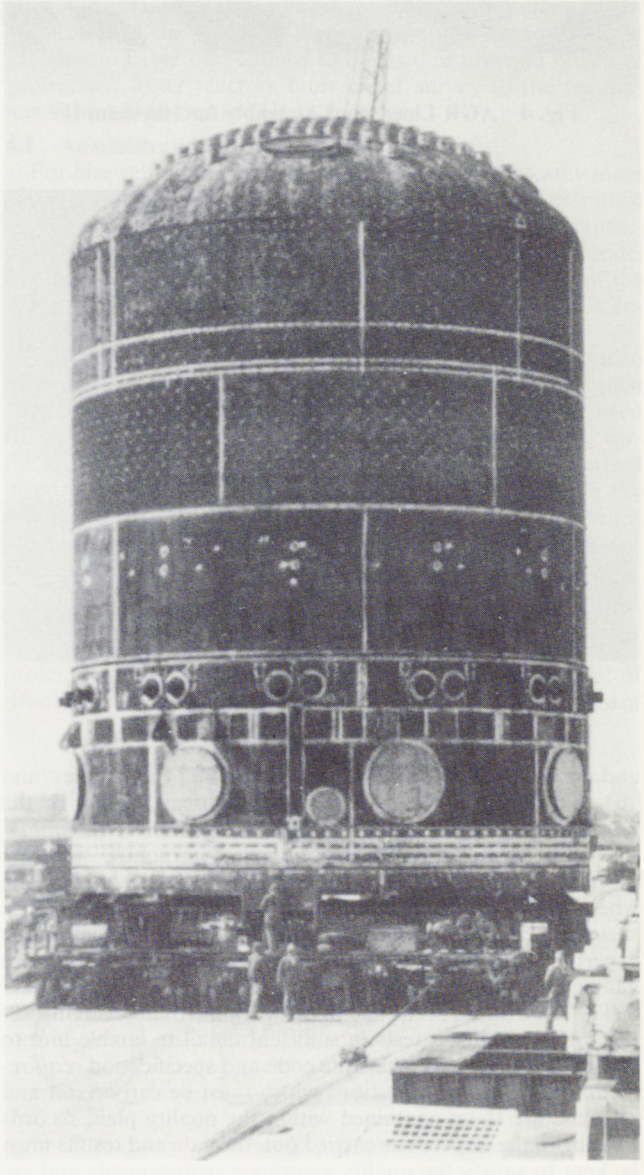


Fig. 3 AGR Gas Baffle for Heysham II

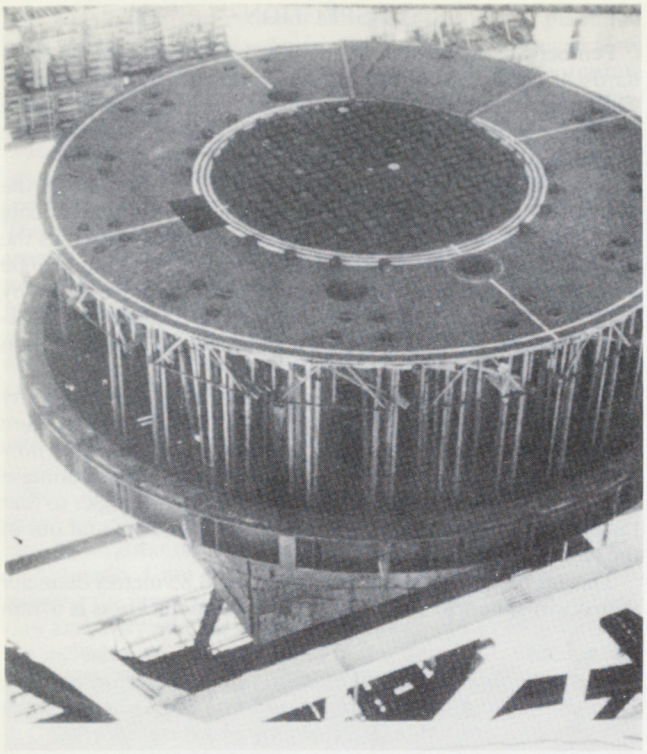


Fig. 4 AGR Liner Roof Assembly for Heysham II



Fig. 5 AGR Liner Wall Assembly for Heysham II

and the central section is perforated with 332 fuel nozzles and 104 interstitial guide nozzles. The cylindrical portion of the vessel is 35mm thick.

At Hinkley Point 'B' this complete structure was site fabricated plate small. Pre-shaped plates were delivered to site where they were erected, welded and post weld heat treated. The successful completion of all these operations owes much to the expertise of the contractors and the utilization of experience gained on the earlier Magnox reactors.

The IIA's duties at site and in the works is to carry out inspections and to witness tests in sufficient detail to enable him to certify that the vessel meets the code and specification requirements. The formal inspections which must be carried out and reported are those contained within the quality plan, records relating to the inspections carried out, the date and results must be kept to satisfy the quality assurance arrangements and are subject to scrutiny by both external and internal auditors.

It is of equal importance that processes such as heat treatment, forming operations and welding are kept under close surveillance so that problems or deficiences can be highlighted at an early date. The combination of what might be termed formal inspections, i.e. those required to be carried out by the approved quality plans and inspection by surveillance provide added assurance that the vessel is built in compliance with the specification and will enter service free of any significant defect.

It is also important that all personnel responsible for inspection should be consulted at an early stage to ensure that the vessel can be properly examined, e.g. all pressure retaining welds should be designed to permit full and reliable volumetric inspection either by radiography or ultrasonic examination. The achievement of this in design is not always possible, e.g. nozzle to shell welds do not permit reliable radiography and the geometry is such that it is difficult to obtain 100% coverage by ultrasonic test. Additionally it is not always possible to predict faults which may occur during a manufacturing process or which due to the limitations of the inspection techniques could go undetected.

5.1 Manufacturing Faults

In the AGR there are twelve boiler units Figs. 6 and 7 each consisting of economiser, evaporater, superheater and reheater sections. The boilers are of the once through type and the banks of tubes which form the boiler sections are arranged in a serpentine fashion with each tube supporting its adjacent tube by welded spacer bars. In each boiler unit there are 25,500 m of tubing, 3750 butt welds and 182,500 spacer welds.

The tube material is 1% Cr 0.5% Mo for the economiser section, 9% Cr 1% Mo for the evaporater and primary superheater and 316 austenitic stainless for the secondary superheater and reheater sections. The spacer bars are of compatible material and are about 35mm wide by 4mm thick. In order to maintain a consistent level of spacer bar to tube weld quality an automatic welding process involving the use of industrial robots was developed together with the adoption of pulsed-MIG welding. In addition a number of welds were made by the TIG welding process.

Despite the elaborate precautions taken during the proving trials of these machines and the conducting of weld procedure qualification and daily tests, problems of tube wall melt-through at the spacer attachment (Fig. 8) were experienced and could not be readily detected because only a small percentage of the bores of the tubes were available for inspection using fibre optics.

The two main factors affecting weld penetration are arc current and travel speed. Following the discovery of these defects the welding parameters were optimised at the lower end of the range of the proven weld procedure qualification. The detection of melt-through was eventually made possible by pressurised bore purging during welding, the onset of melt through being detected by the ejection of a small amount of the weld pool.

Other problems have been experienced as might be expected during the course of construction of these major projects. Some of these problems are listed as follows:-

Defect – Carburisation of the bores of 9% Cr tubes
Cause – Graphite lubricant used on drawing mandrel
Found by – Failure at purchaser's works during bending.

Defect – Copper contamination of stainless steel
Cause – Contamination of cutting fluid.
Found by – Repeat dye penetratant examination at purchasers works.

Defect – Lead contamination of stainless steel tubes
Cause – Pick up from inspection table
Found by – Visiting Surveyor.

Defect – Scale in austenitic stainless steel tubes
Cause – Oxygen in furnace gas
Found by – In process manufacturer at purchaser's works.

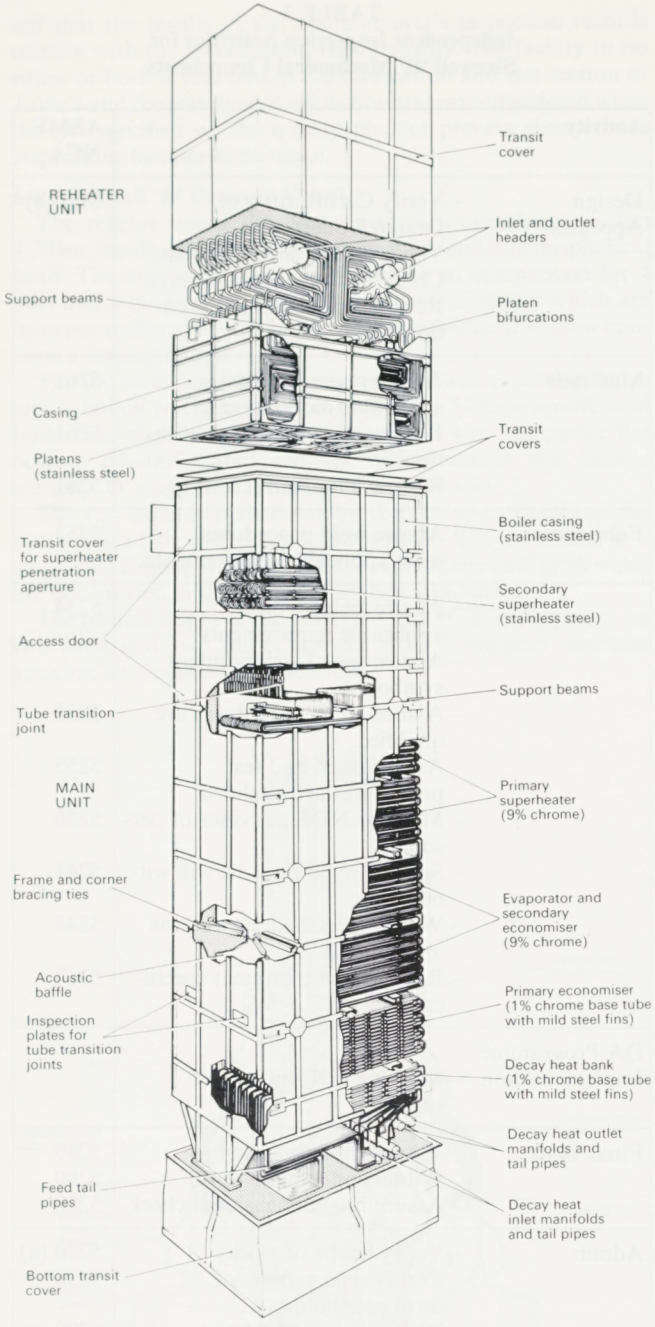


Fig. 6 AGR Boiler Unit

Defect – Incorrect welding electrodes being used during welding.
Cause – Unknown
Found by – Site Surveyors during routine surveillance.

These problems can be attributed to failure of the quality assurance programmes. Failure to identify problems, either in the design and review of manufacturing procedures or by breakdown of the quality activities in the works. The problems were found by inspection or as a result of a subsequent manufacturing operation and they emphasise the continuing need for proper and responsible review of manufacturing techniques, procedures and competent inspection at all times.

6. SIZEWELL B

The Sizewell 'B' reactor pressure vessel will be the 12th such vessel built under survey with L.R.I.S. acting as the IIA. Other

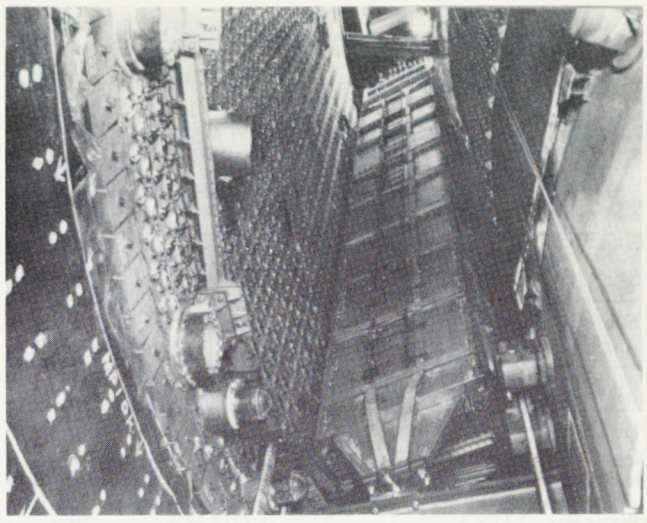


Fig. 7 AGR Boiler in Annulus

reactor systems built under survey include the Steam Generating Heavy Water Reactor at Winfrith, research reactors Pluto and Dido at Harwell with some involvement with Boiling Water Reactors and the U.K.A.E.A. prototype fast reactor plant at Dounreay. Table 2 is confined to the reactor pressure vessels of pressurised water reactors built under survey to the requirements of ASME Section III.

6.1 Administration Requirements

For Sizewell 'B' the preconstruction safety reports, statement of case and proof of evidence presented to the Sizewell 'B' public enquiry identified the CEGB's intention to design and manufacture the reactor coolant system to the ASME Section III code. For those parts manufactured outside the USA the role of the Authorised Nuclear Inspector will be performed by the Independant Inspection Authority (IIA).

The administration requirements of the ASME code relate to institutions and practices which are specific to the U.S.A. such as the code symbol stamping of manufactured items, the need for owners and their suppliers to obtain, from ASME, certificates of authorisation and the employment of an authorised inspection agency. Whilst LRIS (Insurance) Inc provide the services of an authorised inspection agency there nevertheless remained a need for the CEGB to make certain changes to the administration requirements to suit UK practices.

For non-U.S. supplied items the changes made related to the maintenance of the control function represented by certification of design documents without limiting the qualifications to a professional engineer registered in the U.S.A., the removal of the need for the owner and his suppliers to obtain a certificate of

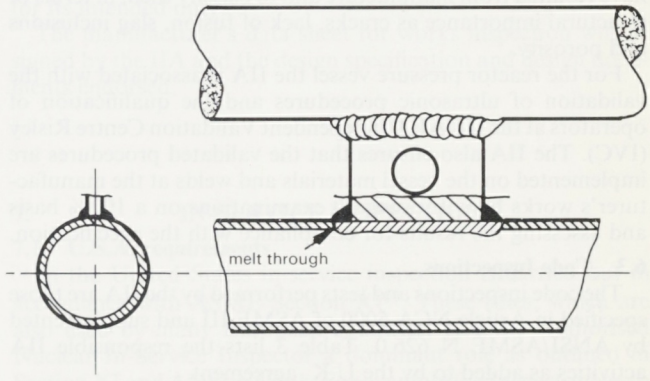


Fig. 8 Spacer-tube Weld Section

TABLE 2
PWR REACTOR PRESSURE VESSELS

NAME OF PLANT	LOCATION	NO. OF VESSELS	OUTPUT PER UNIT	DATE OF COMPLETION
Surry 1 & 2	U.S.A.	2	848 MWe	1971
Sequoyah 1 & 2	U.S.A.	2	1124 MWe	1972
North Anna 1 & 2	U.S.A.	2	800 MWe	1972
Ringhals	Sweden	1	840 MWe	1972
Duke 1 & 2 (William B. McGuire	U.S.A.	2	1220 MWe	1974
Watts Bar 1 & 2	U.S.A.	2	1218 MWe	1974
Sizewell B	England	1	1182 MWe	1990

authorisation, a change from ASME Section III quality assurance arrangements to BS 5882 and to provide for code inspections to be carried out by an IIA under contract to the owners CEGB.

The IIA role for the Sizewell 'B' project is greater than that given in ASME Section III due to the additional requirements for design appraisal and inspection witness activities for items of plant for which claims have been made for incredibility of failure (I.O.F) in service.

I.O.F. is claimed for components of high quality material whose structural integrity has been proven by comprehensive analysis and have successfully passed all diverse and redundant examinations. The I.O.F. components are the RPV and its core support structure, primary components including the steam generators and the pressuriser and circulating pump bowls.

6.2 Ultrasonic Inspection

The diverse and redundant examinations are carried out on the vessel materials and the welded seams by different teams of qualified ultrasonic operators using ultrasonic procedures and equipment which have been validated on test pieces containing implanted flaws. The test pieces simulate as near practicable the shape, size and material of the vessel components.

The inspection techniques and the ability of the operator to locate and size defects therefore undergoes close scrutiny prior to the actual examination of the production components being carried out. The sensitivity of the examination has to be such that it is capable of detecting small material defects which may have resulted from manufacture and to classify them in terms of structural importance as cracks, lack of fusion, slag inclusions and porosity.

For the reactor pressure vessel the IIA is associated with the validation of ultrasonic procedures and the qualification of operators at the UKAEA Independent Validation Centre Risley (IVC). The IIA also ensures that the validated procedures are implemented on the vessel materials and welds at the manufacturer's works by witnessing all examinations on a 100% basis and assessing the results for compliance with the specification.

6.3 Code Inspections

The code inspections and tests performed by the IIA are those specified in Article NCA 5000 of ASME III and supplemented by ANSI/ASME N 626.0. Table 3 lists the responsible IIA activities as added to by the U.K. agreement.

Vendor appraisal is normally carried out by the CEGB, and the quality assurance evaluation, audit reports and documentation are made available to the IIA to enable participation by the IIA in subsequent audits and for the purpose of monitoring the performance of the supplier.

TABLE 3
Independent Inspection Activities for Sizewell 'B' Mechanical Components

Activity		ASME NCA
Design Appraisal	– Verify Certification of Design Documents. – Validation of stress analysis. – Check to Code requirements. – Review equipment specifications.	5230(b)
Materials	– Assure materials meet applicable requirements. – Review all material specifications. – Review all material tests.	5261 5261 5261
Fabrication	– Assure weld procedures meet applicable requirements.	5253
	– Assure welders meet applicable requirements. – Assure use of welder intent symbol. – Assure NDE procedures are qualified. – Assure exam and test procedures are qualified. – Monitor NDE activities of personnel. – Specify inspections he will witness. – Witness specified inspections and sign off. – Review heat treatment specifications.	5254 5255 5255 5256 5241 5243 5263
QA Programme Implementation	– Monitor performance of supplier.	
Final Tests	– Witness hydraulic test. Witness pneumatic test. Assure final dimensional check.	5280 5280 5280
Admin	– Verify Scope of work – Certify data reports of certificate holder. – Verify the overpressure protection document.	5230 (a) 5290 5290 (c)

The code requirements for inspections and tests require the authorised inspector to witness the final hydrostatic, pneumatic, or structural integrity tests, the remainder of the inspectors duties are considered satisfied if the inspector either verifies or assures himself, presumably by review of the manufacturer's inspection data or other means, that all code examinations have been carried out. He does have freedom at all times to those locations where code activities are taking place and he can also make any other inspection other than the code examinations which in his opinion is necessary to ensure code compliance of the item.

It is customary in the U.K. nuclear industry that the IIA will witness or perform the inspection activity and also satisfy him-

self that the results of the manufacturer's inspection records comply with the specification requirements. The facility to do either or both is reflected in the fabrication and test section of Table 3 and the selection of inspection stages is considered when the IIA specified on the quality plan or process sheets those inspections he intends to make.

6.4 Sizewell 'B' Pressure Vessel

The reactor vessel Fig. 9 consists of a cylindrical section 4.394m, inside diameter and 215mm thick and a hemispherical head. The nozzle course is 267mm thick to compensate for 4 inlet and 4 outlet nozzles of 737mm inside diameter which are incorporated within it. The top of the cylindrical section contains a bolting flange.

The top head assembly is hemispherical with a bolting flange and is bolted to the cylindrical section by 54 high tensile steel bolts. The shell and head flanges contain two concentric flat bottom circumferential grooves which receive two hollow metallic 'O' rings to seal the vessel to head joint.

The top head is penetrated by control rod drives and the bottom head by instrumentation nozzles. The core shell is a single ring forging which means that circumferential girth welds are not located in the region of highest irradiation.

The overall height of the vessel is 13.660m. It is supported on two inlet and two outlet nozzles from a support structure attached to a concrete foundation.

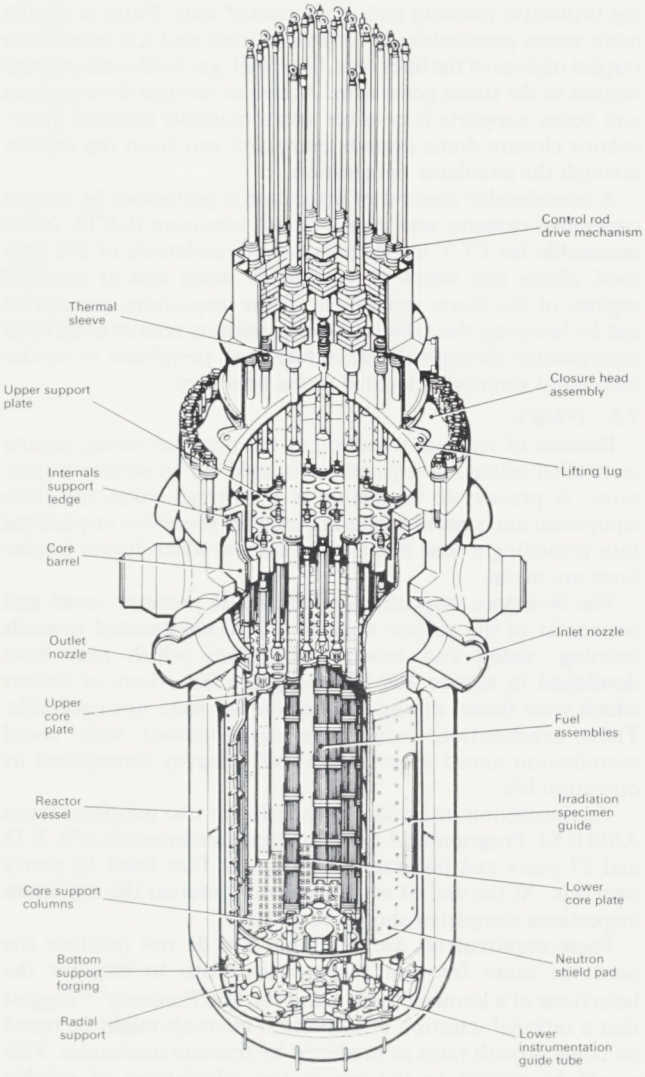


Fig. 9 PWR Pressure Vessel

The design conditions are:-
Design pressure 17.13 MPa
Design temperature 343°C

6.5 Materials

The vessel is made from medium carbon steel ring forgings conforming to ASME SA 508 class 3 but with tighter control on residual elements to improve steel cleanliness, weldability and overall ductility. Further controls are placed on copper, vanadium and phosphorus for the base material and weld metal of the core shell region. These controls are aimed at limiting the in-service deterioration of material properties due to irradiation.

The inside surface of the vessel is clad by welding to it a thin layer of corrosion resistant stainless steel. The cladding is applied using automatic submerged arc welding employing strip electrodes 60mm wide.

The use of cylindrical forgings reduces the amount of welding by the elimination of longitudinal seams. The volume of weld metal and hence the probability of weld defects is further reduced by using narrow gap welding for the circumferential seams.

Welding material acceptance tests for the submerged arc welding wire and flux combinations are witnessed. Tests taken from a deposited weld metal include, tensile, charpy, chemical analysis and drop weight tests to determine the nil ductility transition temperatures.

6.6 Weld Procedure Testing

Weld procedure tests are performed on full thickness test pieces on material conforming to the vessel requirements. Separate procedure tests are performed for each different weld preparation used in construction and for the welding of the vessel heads to shell. To demonstrate the capability of welding under conditions of restraint the nozzle to shell weld procedure test is performed on a full size mock up by welding a nozzle into a half shell of full vessel thickness.

On completion of welding the test plates are subject to full ultrasonic and radiographic examination. Test pieces are cut and mechanical tests carried out in accordance with ASME Section III and ASME Section IX requirements. These are supplemented by Charpy tests for determination of the transition curve, drop weight tests for determination of the reference nil ductility transition temperature and fracture toughness measurements (J_{IC}) tests on material taken from the weld metal and heat affected zones at test temperatures, 43°C and 293°C. These temperatures represent the shut down and operating temperatures of the reactor pressure vessel.

6.7 Certification

Certificates are issued at the various stages of fabrication and on completion of the pressure vessel. A complete dossier of material test results, inspections performed during manufacture and the results of non-destructive tests is compiled for issue to the CEGB. The certificates will reflect that the reactor vessel conforms to the Contract Specification and that it is entirely fit for its intended duty.

The manufacturer's data sheet for works inspection will be signed by the IIA and the design specification and design documents endorsed.

7. IN-SERVICE INSPECTION

7.1 U.S.A. requirements

In the United States in-service inspection is carried out in accordance with ASME Section XI[9]. These rules, which are also used by many European countries, give the Authorised Nuclear In-Service Inspector a dominant role as outlined in Section XI and ANSI N626.1. For example the Inspector has to verify that the Owner adheres to his quality assurance programme for in-service inspection activities and that the

results of all inspections are properly documented and meet the code requirements. All examinations required by Section XI are completed prior to plant start up and generally cover 100% of all pressure retaining welds in Class 1 components.

The inspections of the reactor pressure vessel are performed after the hydrostatic test required by ASME Section III is completed. These inspections are carried out with equipment and techniques equivalent to those expected to be employed during the in-service inspections.

The assessment and acceptability of defects found which exceed the code allowable indications are evaluated by analytical procedures based on fracture mechanics or are repaired. Volumetric examination by ultrasonics is used for the detection of crack or crack-like defects, the requirement being to provide a 100% in-service examination of all welds at 10 yearly intervals during the vessel life.

7.2 U.K. Practice

In the United Kingdom there are no British Standards covering in-service examination of nuclear plants. The licensees of nuclear plant are required to develop their own in-service inspection arrangements and to submit these to the NII for consideration. The responsibility for nuclear safety remains at all times with the licensee, and it follows that the standards he employs must be selected by him.

The Society has been involved with the in-service inspection of nuclear plant at the U.K.A.E.A. establishments at Calder Hall and Chapelcross and has also been represented on the Periodic Inspection Committee (PIC) since its inauguration atthese plants in 1956. Subsequent committees at the Steam Generating Heavy Water Reactor (SGHWR) Winfrith and the Prototype Fast Reactor (PFR) Dounreay have also been attended since their inauguration.

In general the terms of reference of the P.I.C. is to advise the Safe Working parties by:-

(a) Establishing a comprehensive list of those inspections and tests, and the frequency thereof, which are required to sustain the reliability claims included in safety arguments, and those inspections and tests which are required to meet statutory obligations.

(b) Specifying the procedure for each of these inspections and tests.

(c) Maintaining the lists of inspections and tests and specifications to take into account the experience arising from these plants and recommending any changes considered warranted.

(d) Reviewing the results of inspections and tests and advising on repairs and plant condition for continued operation.

In-service inspection is performed by visual examination supplemented by non-destructive examinations. The non-destructive techniques are dye penetrant examination for austenitic steels, magnetic particle examination for ferritic steels, radiography for butt welds and ultrasonic examination for a wide range of components and weld geometries. Eddy current methods are used to detect flaws in thin welded tubes. For those parts of a reactor vessel which because of radiation levels cannot be readily entered, inspection by remote controlled camera and closed circuit television can be carried out to monitor plant integrity.

7.3 Magnox Reactors

In the earlier type Magnox reactors, based on the Calder Hall design, heat from the reactor core is carried off by coolant gas to the steam generators arranged outside the reactor pressure vessel, a feature which was not used on the later stations. The gas is conveyed through inlet and outlet mild steel ducts approximately 5′.0″ in diameter which are fitted with bellows units to achieve flexibility. This arrangement permits internal and external examination of the gas ducts and examination of the gas-side surfaces of the heat exchangers. These examinations are carried out in radiation supervised areas by Surveyors who have been designated as classified workers in accordance with the Ionising Regulations 1985[10]. Exposure to radiation is monitored by the Health Physics Department of the stations attended and by the Society's appointed radiation advisers through the issue and evaluation of monthly dosemeters. The examinations are carried out at the Reactor Statutory outage and are performed to ensure that there has been no deterioration in plant condition. Visual examinations are supplemented by using N.D.E. methods crack detection and ultrasonics. Each defect indication is recorded and justification presented for repair or returning to service with further monitoring. Using inspection techniques such as ultrasonics which will detect lack of fusion defects and inspection methods which were not used during the original construction can be the cause of much discussion. It is therefore necessary to adopt a rigourous inspection assessment before concluding that a defect is either the result of in-service operation or that it was an original construction fault which went undetected.

For defects which cannot be repaired or are not considered to be significant, a careful programme of in service monitoring is arranged. This requires accurate location and sizing of the defect and repeating the same inspections using the same technique and equipment sensitivity.

7.4 AGR's

Controlled entry to the AGR is possible for personnel wearing protective clothing and or air cooled suits. Entry is via the main access penetration in the reactor roof and it is possible to inspect regions of the liner roof, liner wall, gas baffle and selected regions of the steam generators. Access to the liner floor regions and boiler supports is possible and a manhole situated in circulator closure dome permits entry and exit from the reactor through the circulator penetration.

A considerable amount of inspection is performed by remote controlled cameras and closed circuit television (CCT). Areas accessable for CCT inspections are the underside of the liner roof, above and below the gas baffle dome and at specified regions of the steam generators. These inspections are carried out by lowering the camera together with its remote controlled manipulator through the interstitial and peripheral in-service inspection standpipes located in the liner roof.

7.5 PWR's

Because of residual radiation at the pressure vessel, remote controlled ultrasonic equipment is used for in-service inspections. A pre-service inspection is performed using the same equipment and procedures as are used for in-service inspections thus providing a base line of data against which future inspections are made.

The in-service inspections of the PWR pressure vessel and remainder of the reactor coolant system are directed towards locating, sizing and monitoring defects which may have developed in service and observing the behaviour of defects which were found during fabrication but were not rejectable. These examinations which are supplemented with visual examination aimed at proving vessel integrity throughout its operation life.

The inspection intervals are specified in two programmes in ASME XI. Programme A calls for inspection intervals of 3, 7, 13 and 27 years and programme B requires four fixed 10 yearly intervals. At the end of each inspection interval the minimum inspections completed should be 100%.

These requirements are minimum and do not preclude the need for more frequent repeat inspections to monitor the behaviour of a known defect. Cameron and Pomeroy[11] suggest that a rational selection of inspection intervals might be based on crack growth rates as predicted by fracture mechanics. This would be subject to the use in the calculations of reliable material data. Other data relating to the operational history of the plant, the location of defects whether in a low or high stress

region, the defect type and the ability to accurately locate and size the defect would also influence the choice of inspection intervals.

8. CONCLUSIONS

The Society has had a long association with the nuclear power industry since its very early days. Although in recent years there has been a dramatic slow down in new ordering of power plants, due to public concern and political pressure, it is likely that further nuclear installations will be built. To allay public concerns it is also likely that the role of the independent inspector will be more important. This was clear when the Society was called to provide key evidence to the public enquiry relating to Sizewell "B".

It is likely that in the future the Society's involvement will differ considerably from the direct inspection role of the early stations. It will involve a far greater involvement in quality management of design, manufacture and commissioning including the audit of relevant documentation.

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8. H. N. Pemberton and E. Crossley: "Inspection of Primary Circuits and Reactor Pressure Vessels of Nuclear Power Plant".
9. ASME Boiler and Pressure Vessel Code Section XI Division 1: "Rules for Inservice Inspection of Nuclear Power Plant Components".
10. Ionising Radiations Regulations 1985: Statutory Instruments 1985 No. 1333.
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APPENDIX 1

	DESCRIPTION	Applicable B.S. Specification or A.S.M.E. Code	Design Appraisal to Basic Code Requirements Including where appropriate Validation of Stress Analysis.	Materials					Fabrication									Final Acceptance Tests & Checks						Key
				Mechanical Tests	Chemical Analysis	Material Identification	Non-Destructive Exams.	Prototype/Design Tests	Weld Procedure Tests	Welder Qual. Tests	Production Tests	Inspection during Fabn.	Crack Detection (N.D.E.)	Radiography	Ultrasonic Examination	Heat Treatment	Shop Hydraulic Test	Hydraulic Pressure Test	Leak Test	Pneumatic Pressure Test	Dimensional Check	Visual Examination	Performance Test	A. Tests witnessed & certified by Inspecting Authority B. Manufacturers works tests certificates accepted.
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Notes
	REACTOR PRESSIRE VESSEL (R.P.V.) STRUCTURE																							
241	Reinforcement for Concrete R.P.V.			A	B	A																		
"	Stressing Tendons	2691		A*	B	A*		A*			A*											A		* See Note 1
"	Ducts	3617		A	B	A																		
"	Anchor Trumpets, Anchor Boxes and Bearing Pads		B	B			A*																	* See Note 2
	PRESSURE VESSEL STEEL LINER ETC.																							
243	Vault Liner	"	√	A	B	A	A*	A	A	A	A	A	A*	A*	A*	A			A	A	A	A		* See Note 3
"	Liner Attachments	"	√√	B	B	A			A*	A	A*	A	A		A	A					A	A		* See Note 4
"	Penetrations including Retention and Containment	"	√	A	B	A	A*	A	A	A	A	A	A*	A*	A*	A	A	A*	A	A	A	A		* See Note 5
"	Cooling pipework up to first Isolating Valve	806 2633	√	A	B	A			A	A		A	A	A					A*	A	A	A*		* See Note 7
242	Penetration Liners	3915	√	A	B	A	A*	A	A	A	A	A	A*	A*	A*	A	A	A	A	A	A	A		* See Note 5
"	Standpipe Liners	"	√√	A	B	A	A*	A	A	A		A	A*	A*	A*	A	A	A	A	A	A	A		* See Note 5
"	Attachments	"	√√	B	B	A			A*	A	A*	A	A*		A*	A					A	A		* See Note 4
"	Cooling Pipework up to first Isolating Valve	806 2633	√	A	B	A			A	A		A	A	A					A*	A	A	A*		* See Note 7

APPENDIX II

	QUALITY PLAN	MODULE S 9 sheet 1 of 2 Welding (Class 1)	Rate QC.77b – Balanced Erection j – Standard Erection h – Run-on-Site Erection

STAGE No	STAGE DESCRIPTION	DEPT. RESP.	CONTROL DOCUMENTS PROCEDURE (CD)	C.D. MARK-UP				VERIFYING RECORDS/ DOCUMENTS (VR)	V.R. MARK-UP				INSPECTION AND SURVEILLANCE				STAGE No.
				A	B	C	D		A	B	C	D	A	B	C	D	
1	Verify Welding Procedure Approval	W.X.	Welding and NOTE Data Schedules (WNDS)					BAS Sheets ref on WNDS	R1		R1						1
2	Verify Welder Qualification	W	QCP 70/7/1					Qualification Cert.	R1		R1						2
3	Check fit up and cleanliness of joints	X	QCP 70/8/1					Report Form QC.31 & Form QC.77b, j or h					A1		b2		3
4	Issue and record filler wire batch numbers	W	QCP 70/7/1					Report Form QC.31 & Form QC.77b, j or h			R2						4
5	Check preheat for rest run	W	Weld Procedure and sheet 2401–294					Recorder Chart	R1		R2				s		5
6	Deposit rest run	W	Weld Procedure												s		6
7	Record Welder identity for Rest Run	W	QCP 70/7/1					Report Form QC.31 & Form QC.77b, j or h			R2						7
8	Visually examine rest run	X	QCP 70/8/1					Report Form QC.31 & Form QC.77b. j or h					A1		s		8
9	Issue and record Batch nos. of Fill Consumables	W	QCP 70/7/1					Report Form QC.31 & Form QC.77b, j or h			R2						9

NOTE: FOR THE SIGNIFICANCE OF THE VARIOUS CODES USED PLEASE REFER TO PAGE 1 OF THIS QUALITY PLAN

A	ORIGINAL		
		DATE	
		AUTHOR	
		APPROVED QUALITY CONTROLLER	
		APPROVED CONTRACTS	

NON-DESTRUCTIVE EXAMINATION OF SIZEWELL 'B' COMPONENTS

by
R. Porter



Roger Porter first became involved with applied Non Destructive Examination, N.D.E., whilst employed as a Metallurgist at Parker Foundry, Derby. This Metallurgical origin resulted in Professional Membership of the Institute of Metals. A closer insight into the theory of N.D.E. was gained whilst employed as a Scientific Officer in the Research Laboratories of British Railways also at Derby. He joined Lloyd's Register Services in 1970 ostensibly at Industrial Services, Croydon but based at Crawley. Since then the N.D.E. Services group, of which he is now Principal Surveyor, has provided both practical and advisory services in N.D.E. related matters to Marine, Offshore, Training and Industrial departments within the Society. During the last four years Sizewell 'B' related work has expanded to become the largest single N.D.E. project within the Society.

TABLE OF CONTENTS

1. INTRODUCTION
2. EXTENT OF TESTING
   2.1 General
   2.2 Stages of Testing
3. PROCEDURES
   3.1 Requirements
   3.2 Procedure Validation
   3.3 Acceptance Criteria
4. PERSONNEL
5. CONCLUSIONS
6. BIBLIOGRAPHY

1. INTRODUCTION

There are many different types of nuclear reactor operating in the world today. A full description of the nuclear process and of the main types of reactors was given in the paper presented to the Technical Association by Hildrew.

Since then the Pressurised Water Reactor, (PWR), has become the most widely used nuclear power plant system in the world. At present there are 89 PWRs operating in fifteen European countries with a further 54 planned for installation. A large number of PWRs provide power for the world's nuclear submarines.

The PWR uses water loaded with Boron in the form of Boric acid to act as both moderator for the nuclear process and as heat transfer agent.

Water is forced through the primary circuit of the Reactor by Coolant Pumps, entering the Reactor Pressure Vessel, (RPV), via the Inlet Nozzles, passing through channels in the Reactor Core and exiting via the Outlet Nozzles. The heated water travels through the stainless steel piping of the Coolant Loops into the Steam Generators. Heat transfer takes place in the Inconel vertical U tubes of the Steam Generators, the water being pumped back to the RPV, completing the cycle. The temperature of the water at the outlet nozzles of the Reactor Pressure Vessel is approximately 340°C and it is necessary to subject the system to a pressure of up to 172 bar in order to prevent the coolant water from boiling. This pressure is created and maintained by the use of electric heating elements within the Pressuriser vessel.

To contain the pressurised water with safety it is necessary to construct thick walled pressure vessels of very high quality. The Non-Destructive Examinations of these components are of paramount importance.

The first commercial PWR to be installed in Britain will be sited at Sizewell in Suffolk. The Society has been appointed by the Central Electricity Generating Board (CEGB) as the Independent Inspection Authority for the project. This appointment brings with it an extensive involvement in the Non Destructive Examinations applied to the main components of the installations. These will be described in this paper.

2. EXTENT OF TESTING

2.1 General

It is notable that the introduction of each new generation of nuclear power plant has been accompanied by an escalation in the extent of the applied non destructive examinations. This has occurred partly because more searching methods such as ultrasonic testing have become available and also because it has been necessary to allay the increased public concern regarding nuclear installations. It is interesting to note that the first plant constructed under Society survey was built without the advantage of ultrasonic testing and that the inspection procedure employed in the early 'fifties' would be regarded as inadequate by today's standards.

Major surveys of the older Magnox reactors have been made to justify an extension of the reactor life. During these surveys ultrasonic examinations of welds whose configurations were not amenable to radiography during construction have revealed significant weld defects such as slag, lack of fusion and incomplete penetration that would be repaired without question if found during construction today. It is interesting also, that there has been no reported evidence of defect propagation in any of these defects despite twenty to thirty years of operating life.

With regard to the Sizewell 'B' PWR, a great deal of emphasis has been placed on the N.D.E. to be applied during fabrication. Features of the N.D.E. such as independent validation of

operators, procedures and equipment, and diversity and redundancy of inspection techniques have been stressed by the CEGB in the safety case presented for the reactor. The implementation of these features has not been without cost, both in terms of money and time. It has been stated that the inspection costs for the Reactor Pressure Vessel (R.P.V.) alone will exceed the cost of the vessel itself and that a similar sum will be expended on the inspection of other primary circuit components. It has also been stated that similar sums will be expended on validations of N.D.E. procedures, equipment and personnel[1].

To obtain the licence for Sizewell 'B' it has been necessary for the CEGB, in their safety case, to detail the extent of the non destructive testing to be applied both during construction and later, in-service. A feature of the safety case has been that of the 'Diversity and Redundancy' of ultrasonic examinations whereby the most important components are subjected to repeat examinations performed by different teams using different procedures. The Society, as Independent Inspection Authority, is required to witness all ultrasonic inspections, including 100% witnessing of ultrasonic inspections applied to R.P.V. components, to ensure that all are carried out strictly in accordance with the approved procedures and, where relevant, in accordance with the conditions under which validation certifications have been issued.

Essentially, the most important components in the primary circuit are deemed to be the R.P.V. itself and those other components whose failure must be regarded as not credible, i.e. the I.O.F. (Incredibility of Failure) components. I.O.F. components identified to date include the R.P.V., the steam generator pressure boundaries, the pressuriser shell, the reactor coolant pumps (R.C.P.), the reactor internals, the emergency core cooling system accumulators, and certain line pipe runs including the primary coolant pipework.

2.2 Stages of Testing

The primary circuit pressure vessels with the exception of the R.C.P., are fabricated by welding together forged rings, nozzles and heads as appropriate. The forgings from which the Reactor Pressure Vessel is assembled are shown in Fig. 1. A welded nozzle shell assembly is shown in Fig. 2.

The main forgings are ultrasonically examined prior to welding and cladding at more than one stage, the first examination being an 'in-house' or non-contractual inspection made by the manufacturer followed by at least two inspections made usually by other contractors appointed by the C.E.G.B.

Forgings for the R.P.V. are examined in the roûgh machined condition before and after heat treatment and further machining, the pre heat treatment inspections being restricted to those volumes where surface profile after machining to shape would affect the efficiency of the applied examinations. These manually applied examinations are finally followed by an automatically applied examination, the automatic equipment including a Sonolog 83 flaw detector manufactured by R.T.D.

Welds in the R.P.V. are examined by manual ultrasonic techniques at the fabrication stage before and after cladding and again after post weld heat treatment.

Additional automated ultrasonic examinations of RPV welds are made during the construction phase in the case of nozzle to shell welds and after hydraulic testing in the case of the circumferential girth welds. Finally, automated pre-service inspections of the welds in the completed vessel are made at the fabricators and again on site using the equipment designed for subsequent in service inspections.

A list of the ultrasonic inspections to be applied to the reactor pressure vessel components is shown in Table 1.

The features of diversity and redundancy in ultrasonic inspections applied to the R.P.V. are extended to the other I.O.F. components. Forgings for steam generator and pressuriser shells are examined twice using manual ultrasonic techniques applied by two teams. Similarly, steam generators and pressuriser head forgings in the machined condition are examined by two teams in addition to the inspections applied at the shaping stage. The main circumferential and nozzle welds between these forgings are ultrasonically examined again by two teams using different procedures at both pre and post weld heat treatment stages.

The above paragraphs describe the ultrasonic examinations applied to the main components in the primary circuit. When the ultrasonic testing of other items within the primary circuit such as steam generator tubing and channel head divider plates,

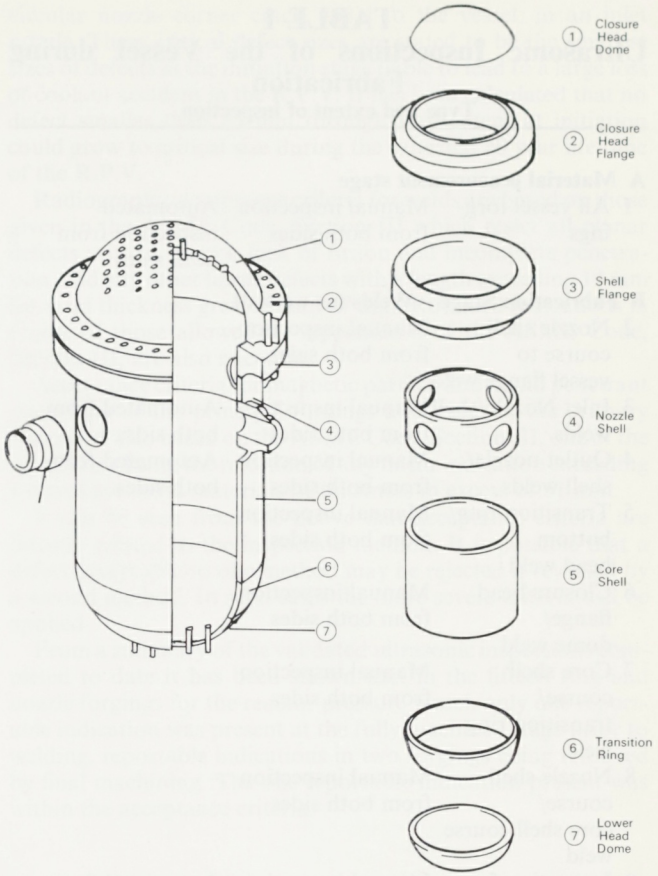


Fig. 1 Reactor Pressure Vessel Forgings

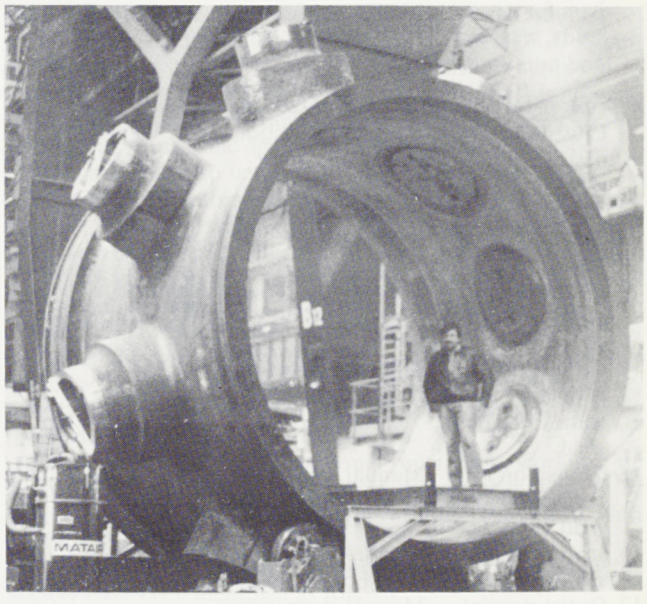


Fig. 2 Welded Nozzle Shell Assembly

TABLE 1
Ultrasonic Inspections of the Vessel during Fabrication
Type and extent of inspection

A	**Material procurement stage**		
1	All vessel forgings	Manual inspection from both sides	Automated inspection from both sides
B	**Fabrication Stage – Welds (as welded)**		
2	Nozzle shell course to vessel flange weld	Manual inspection from both sides	–
3	Inlet Nozzle/shell welds	Manual inspection from both sides	Automated from both sides
4	Outlet nozzle/ shell welds	Manual inspection from both sides	Automated from both sides
5	Transition ring/ bottom head weld	Manual inspection from both sides	–
6	Closure head flange/ dome weld	Manual inspection from both sides	–
7	Core shell course/ transition ring weld	Manual inspection from both sides	–
8	Nozzle shell course/ core shell course weld	Manual inspection from both sides	–
9	Inspection for underclad cracking	Manual inspection from inside only	Automated from inside only
10	Inspection of bars for studs, washers and nuts	Manual	–
C	**Post stress relief inspection of full penetration butt welds**		
11	Closure head/ flange dome weld	Manual inspection from both sides	
12	Vessel flange/ nozzle course weld	Manual inspection from both sides	
13	Nozzle shell course/core shell course weld	Manual inspection from both sides	
14	Core shell course/ transition ring weld	Manual inspection from both sides	
15	Transition ring bottom head weld	Manual inspection from both sides	
16	Inlet nozzle/ shell welds	Manual inspection from both sides	
17	Outlet nozzle/ shell welds	Manual inspection from both sides	
D	**Post-hydro inspection stage – Full penetration welds**		
Items 11–17 above		Automated inspections from both inside and outside the vessel	
Items 12–17 above plus nozzle inner radius		Remote automated inspection from inside only using in-service inspection equipment	
18	Closure head flange/dome weld	Automated inspection from outside only using in-service equipment	
19	Nozzle/shell welds	Automated from outside only	
20	Inspection of studs and nuts	Using in-service inspection equipment	

n.b. Inspections of clad components are generally made before and after cladding.

R.C.P. casings and the R.P.V. core support system is considered it is apparent that an enormous amount of ultrasonic testing is to be performed and witnessed.

Radiography applied to primary circuit components is less extensive, the principal items being the cast austenitic steel R.C.P. casing and the main pressure vessel girth and nozzle safe end welds. These items are subject to full radiography, one of the purposes being to fulfill the requirements of the ASME Code, Section III. Due to the thicknesses involved, e.g. 140 mm to 275 mm in the R.P.V. and 100 mm to 120 mm in the steam generators, it is necessary to use high energy sources of radiation such as linear accelerators and Cobalt gamma ray isotopes in order to achieve satisfactory results.

The surfaces of all forgings and welds in the primary circuit are subjected to a form of surface defect detection, either magnetic particle testing for ferritic components or dye penetrant testing for the austenitic items. Flaw detection of tubing for the steam generators is done by eddy current testing and supplementary ultrasonic testing using an automated system, tube to tubesheet welds being examined by the liquid penetrant method.

From the information already available it is clear that the extent of the non destructive testing applied to Sizewell 'B' components is probably beyond that applied to any previous nuclear installation. The CEGB believe that the R.P.V. will be the single most highly inspected component ever fabricated[2].

3. PROCEDURES

3.1 Requirements

N.D.E. procedures for Sizewell 'B' are written to fulfill the requirements of the ASME Code and to meet the additional requirements of the CEGB. The Society as the Independent Inspection Authority is responsible for endorsing the procedures and, by witnessing and surveillance activities, confirming that the procedures have been satisfactorily implemented.

Equipment specifications for the components in the primary circuit have been prepared by the CEGB. These specifications identify the base requirements for non destructive examinations in terms of methods to be applied, coverage, sensitivity levels, reporting levels and acceptance criteria.

The N.D.E. contractor carrying out the examinations will prepare a detailed procedure for the examination of each weld or forging which will be based on the requirements of the equipment specification.

The ultrasonic procedures for Sizewell 'B' must satisfy the requirements of the CEGB for diversity and redundancy. Diversity of inspection has been established by the use of multiple probe angles, by using additional techniques such as tandem probes or multi-probe arrays, by using special probes such as 70° longitudinal wave probes for sub-cladding crack detection, by selecting probe angles to match weld configurations, e.g. the 53° probes used in R.P.V. nozzle weld inspections, by inspection from inside and outside surfaces, by scanning in opposing directions and by using additional detection methods such as obscuration and crack tip diffraction.

Redundancy is achieved by having repetitive inspections either by using two teams of manual operators or by supplementing manual inspections with automated inspections.

The sensitivity levels established for ultrasonic inspections are higher than those required by the ASME Code. For shear wave

pulse echo inspections a recording threshold of 10% DAC (Distance Amplitude Correction), based on side drilled holes of diameters between 6 mm and 11.2 mm according to component thickness, has been established. For shear wave, tandem probe scanning, the reference level is established from 6 mm diameter flat bottomed holes and for compression wave inspections a comparable reporting level based on 2 mm flat bottomed holes has been used.

When the dimensions of the forgings are considered, for example, the R.P.V. core shell forging at the time of testing measured approximately 5 m diameter, 400 mm thickness, and 3 m length, it can be seen that an exceptionally high standard has been set. Since no reportable indications were observed in this forging it can be seen equially that the required manufacturing standard has been achieved.

3.2 Procedure Validation

Ultrasonic procedures prepared by the N.D.E. contractor will be reviewed by at least four parties: by the purchaser, CEGB, by the main contractor, Westinghouse, by the Inspection Validation Centre, I.V.C., and by the Independent Inspection Authority, Lloyd's Register, who is required to assess and endorse all N.D.E. procedures.

Procedures may require several revisions before being submitted formally to I.V.C. for validation.

Validation of procedures requires both practical and theoretical justifications, the practical aspects of validation being monitored by the N.D.E. Surveyors.

Practical validation of procedures and equipment consists essentially of applying the procedures to test assemblies of appropriate size and configuration. The test assemblies used for validation contain deliberately inserted defects in positions and of sufficient size range to achieve two things:-

(a) certification by I.V.C. that the procedures are capable of finding and accurately sizing with high reliability defects of structural concern, (i.e. Defect heights greater than 15 mm for near surface planar flaws and greater than 25 mm for embedded flaws).
(b) notification by I.V.C. that the procedures are capable of finding and sizing with good reliability defects in the acceptable and unacceptable range in accordance with the purchasing acceptance standards.

Schedules of forging and weld defects of structural concern have been prepared by the CEGB and it is necessary that test assemblies contain defects of the appropriate type. Details of exact defect size and location remain confidential to I.V.C. and to their Management Advisory Committee who control validation activities relevant to the R.P.V.

In addition to validation of practical capability an assessment of the theoretical capacity of an ultrasonic procedure to detect cracks can be made. Computer programs for modelling ultrasonic testing are available and are used to assess the limitations of proposed scanning techniques. Crack detectability can thus be quantified by showing:-

(a) which probe angles will detect a simulated crack,
(b) what signal amplitude will be attained, and
(c) the probe location necessary for the detection of the crack.

3.3 Acceptance Criteria

The acceptance criteria applicable to ultrasonic testing of RPV forgings and welds are tabulated in Table 2. These criteria are almost identical to those for other primary circuit pressure vessels such as the steam generators and the pressuriser.

It is worthwhile to compare the R.P.V. acceptance criteria at their most tolerant with the critical defect size calculated for the worst operating condition envisaged.

Whereas the acceptance criteria tolerate a through wall extent of 12 mm for defects in the zones deeper than 75 mm from the surface, the quoted critical defect sizes include a 100 mm crack depth for a semi elliptical, axial, inner surface crack in the belt line region of the core shell, and a 60 mm crack depth for a semi circular nozzle corner crack, axial to the vessel, in an inlet nozzle. These critical defect sizes are stated to be the smallest sizes of defects at the initiation stage liable to lead to a large loss of coolant accident in the R.P.V. It has been calculated that no defect smaller than 25 mm through wall extent at initiation could grow to critical size during the expected 40 year life time of the R.P.V.

Radiographic acceptance criteria for welds are based on those given in the ASME Code, Section III which reject all planar defects such as cracks, lack of fusion and incomplete penetration, and any other linear defects with a length exceeding 19 mm for weld thickness greater than 57 mm. Rounded indications in excess of those allowed by Appendix 6 of the ASME Code, Section III, are also rejectable.

Acceptance criteria for magnetic particle and liquid penetrant inspection of the principal forgings and welds in the primary circuit are also based on the ASME Code, Section III, one of the main items being the rejection of any linear indication exceeding 4.8 mm for those materials of thickness in excess of 51 mm.

It can be seen from the above that acceptance criteria are directly related to the inspection method. It is possible that a defect acceptable to one method may be rejected if revealed by a second method. In such cases the more severe criteria will be applied.

From a summary of the validated ultrasonic inspections completed to date it has been shown that in the fifteen ring and nozzle forgings for the reactor pressure vessel, only one reportable indication was present at the fully machined stage prior to welding, reportable indications in two forgings being removed by final machining. The one reportable indication present was within the acceptance criteria.

4. PERSONNEL

All N.D.E. personnel working on the Sizewell 'B' project will be qualified, usually to Level II, SNT-TC-1A or to the equivalent level of the National Scheme in the country of manufacture. Additionally, the qualifications of all N.D.E. personnel working on the Sizewell 'B' project will be approved by the CEGB to their Standard No. 989904. The Society is required to confirm the CEGB qualification of operators prior to any inspections. Ultrasonic operators applying validated inspection procedures must also be validated on an individual basis.

Ultrasonic operators working on components of the reactor pressure vessel are validated at I.V.C. Risley. Categories of validation have been established for defect location and sizing in R.P.V. forgings, welds, cladding and bars using both manual and automated scanning techniques.

Operators working on the inspection of austenitic castings or welds are to be validated by the CEGB at their Non Destructive Testing Application Centre (N.D.T.A.C.) at Wythenshawe, validations at both I.V.C. and N.D.T.A.C. being witnessed by the Society's N.D.E. Surveyors.

The majority of the ultrasonic operators working on validated inspections of primary circuit components are to be validated by the N.D.E. Surveyors at the Validation Unit established for this purpose.

Categories of validation for those operators validated by the Society have been identified as follows.

Category V1 – Ferritic Shells and Plates
Category V2 – Ferritic Heads
Category V3 – Ferritic Nozzle Forgings
Category V4 – Austenitic Plate
Category V5 – Ferritic Circumferential Welds
Category V6 – Ferritic Nozzle Welds
Category V7 – Stainless Steel Forgings

Validation by the N.D.E. Surveyors comprises assessment of theoretical knowledge and practical ability. Two written examinations are given, one based on general knowledge of

TABLE 2
Acceptance Standards for Ultrasonic Inspection of RPV Forgings

Referable Conditions Applicable to all depth zones:	Rejectable Conditions Depth Zone (see Fig below)	Throughwall Extent	Straight Beam Amplitude (∅ FBH)	Angle Beam Amplitude (ASME DAC)
(a) attenuation at 4 MHz exceeding 20 dB/m (b) fall of back wall echo to below 5% of echo in sound portion (c) structural noise exceeding 2mm FBH (straight beam) or 5% DAC (angle beam) (d) any group of unresolvable defects with an amplitude exceeding 2mm FBH enclosed by an area exceeding 500mm²	A	3mm	3mm	20%
	B	5mm	3mm	20%
	C	8mm	5mm	50%
	D	12mm	5mm	50%

Applicable to all depth zones:

(a) any indication with a length exceeding 100mm

(b) the frequency of indications exceeding 3mm FBH (straight beam) or 20% DAC (angle beam) shall not exceed 10 per sq. m locally or 5 per sq. m overall.

Acceptance Standards for Ultrasonic Inspection of RPV Full Penetration Welds

Referable Conditions

(a) any indication interpreted as a planar defect
(b) in Zone A all indications with amplitude response exceeding a 1.5mm dia. SDH
(c) any indication interpreted as underclad cracking

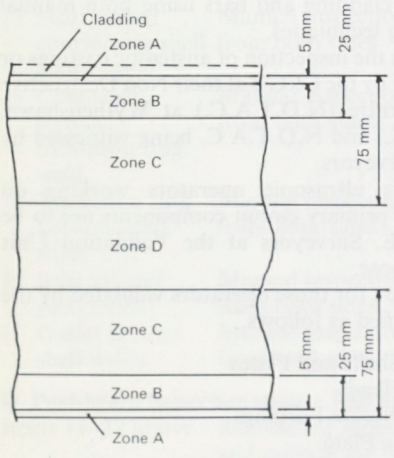
Rejectable Conditions

Pulse-echo Examinations

Zone B – throughwall dimension exceeding 5mm
– length exceeding 20mm and amplitude exceeding 1.5mm dia. SDH
– amplitude exceeding 1.5mm dia. SDH by 6 dB.

Zone C – throughwall dimension exceeding 8mm
– length exceeding 50mm and amplitude exceeding 25% ASME DAC.
– amplitude exceeding 100% ASME DAC.

Zone D – throughwall dimension exceeding 12mm
– length exceeding 50mm and amplitude exceeding 25% ASME DAC.
– amplitude exceeding 100% ASME DAC.



Note: FBH – flat bottomed hole
SDH – side drilled hole

Tandem Examinations

Zones B, C + D – amplitude exceeding 6mm dia FBH.

Pulse-echo and Tandem Examinations

Applicable to all depth zones:

(a) Any indication with a length exceeding 100mm.

(b) Adjacent linearly aligned indications must be combined for the purpose of assessment if the longitudinal distance between the closest points on the indications is less than the length of the longer indication.

Adjacent throughwall aligned indications must be combined for the purpose of assessment if the through-thickness distance between the closest points on the indications is less than the greater of their through-thickness extents.

When defects are combined for the purpose of assessment, the effective dimension is the sum of both the appropriate defect dimensions and separation.

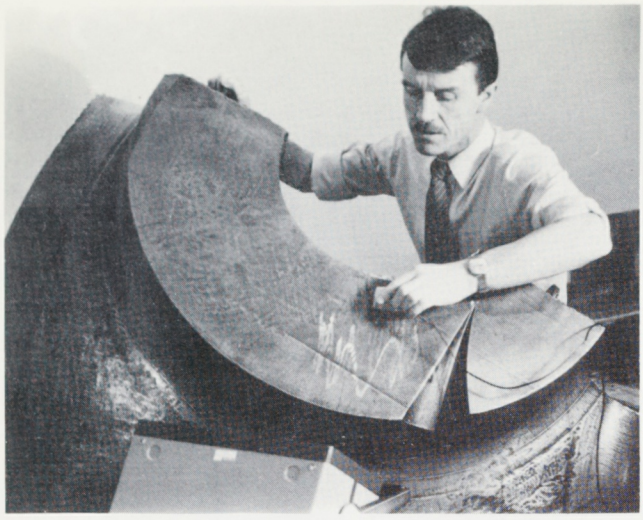


Fig. 3 Verification of Validation testpiece at Crawley

ultrasonic testing, the second based on specific knowledge of the procedures relevant to a given inspection. Practical ability is assessed on two counts, ability to detect and locate defects, and ability to size defects, both within the tolerances identified by the CEGB.

Practical validations are made on test assemblies, Fig. 3, whose size, configuration and defect content must be approved by CEGB – N.D.T.A.C. As with the I.V.C. test assemblies details of exact size and location of defects remain confidential.

5. CONCLUSIONS

The CEGB in their safety case presented to the Sizewell 'B' public enquiry stated that the results of combined validation, and the diversity and redundancy of ultrasonic inspection procedures enabled them to assume with near certainty that the Reactor Pressure Vessel would enter service free from near surface planar defects of greater than 15 mm through wall extent and embedded flaws of greater than 25 mm through wall extent[4].

This assumption has been based on the results obtained from international round robin programmes arranged to assess the capability of the ultrasonic testing method. In programmes such as the Defect Detection Trials[5] held in 1982 and in subsequent programmes such as PISC 2[6] (Programme for the Inspection of Steel Components) completed in 1986, some of the participating teams used procedures and equipments similar to those to be used on the Sizewell 'B' components. Results presented by these teams have provided the basis for the confidence in ultrasonic testing expressed by the CEGB.

As stated previously the CEGB believe that the Sizewell 'B' R.P.V. will be the most extensively inspected vessel ever made. It has been argued that the operating history of Pressurised Water Reactors does not warrant the amount of N.D.E. applied to the R.P.V. The ultrasonic indications in forgings and welds seen to date during construction would almost certainly have been seen during a reduced inspection programme. It has also been argued that no existing flaws of size below the acceptance criteria at the time of construction could possibly grow to significant size during the expected life of the R.P.V. and that the planned in-service inspections of the R.P.V. will therefore be unnecessary.

Why then the emphasis given to the inspection of the R.P.V.? The reason is probably due to public concern regarding the possible failure by melt down of the reactor core giving rise to the 'China Syndrome' incident from science fiction whereby a molten reactor core disappears downwards through the earth's crust. To date, this type of incident has not occurred, despite the human failings of personnel at Three Mile Island and Chernobyl.

Most of the problems associated with light water reactors that have developed in-service have been away from the R.P.V. itself the most widely reported faults having been the failure of welds in stainless steel primary coolant pipework by intergranular stress corrosion cracking in Boiling Water Reactors (B.W.R.) and the failure of Steam Generator tubing in both B.W.R. and P.W.R. by faults such as intergranular attack, intergranular stress corrosion cracking and crushing by oxide formation at tube support plates. The designers of Sizewell 'B' have taken account of these occurrences and by modification of design and selection of appropriate material expect to avoid similar problems.

It is clear then that the Sizewell 'B' N.D.E. programme goes beyond that which would be regarded as essential by technical judgment particularly with respect to the R.P.V. It is clear also that the most important inspections are likely to be those made in-service of components such as the primary coolant pipework and the steam generator tubing. Extensive testing during construction will provide the necessary 'finger printing' for these in-service inspections.

In conclusion, it is believed that the end result of the Sizewell 'B' N.D.E. programme with its features of validation, diversity and redundancy, will be to ensure that the primary circuit components enter service in the 'cleanest' possible condition and free from any defects of structural concern. The Society's N.D.E. role in the reviewing of procedures, validations of procedures, equipment and operators, and the witnessing of inspections is an important part of this programme.

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INTERNATIONAL CONVENTIONS

40 Years on from 1948

L. Beckwith

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Written contributions to the discussion of this paper are invited from members of the Lloyd's Register Technical Association. To ensure inclusion in the discussion paper, the contributions should be received by the Hon. Secretary in London not later than the 31st July, 1988.

Hon. Sec. R. V. Pomeroy
71 Fenchurch Street, London, EC3M 4BS

INTERNATIONAL CONVENTIONS

40 years on from 1948

by

L. Beckwith



Leslie Beckwith served an apprenticeship with Wm. Doxford and Sons, Sunderland from 1943–1948, after which he became a ship design draughtsman with the same firm. He then worked for Bartram and Sons, Sunderland from 1954–1955, when he joined Lloyd's Register in the Freeboard Department at Headquarters. He was transferred to the Ship Research Department in 1959 and then seconded to the Admiralty as Liaison Officer from 1962–1964. On return to Headquarters he served in the Ship Plans and Ship Development Departments before being transferred to the Freeboard Department in 1966 on promotion to Senior Surveyor. He was appointed Principal Surveyor for Tonnage in 1970 and later also resumed responsibility for Stability. He became Principal Surveyor, Convention Co-ordination in 1979, was promoted to Senior Principal Surveyor in 1983 and in the following year took up the appointment of Senior Principal Surveyor, International Conventions. He is the author of several papers on convention subjects presented at international seminars and conferences and has been an Adviser to national delegations at a number of I.M.O. Conferences as well as at various sub-committees of that organisation. He has also represented Lloyd's Register on and eventually became Chairman of the I.A.C.S. working party on Load Lines and Stability.

TABLE OF CONTENTS

1. INTRODUCTION
2. PRE-1948
3. 1948 SOLAS
   - 3.1 International Maritime Organisation (IMO) (formerly Inter-Governmental Maritime Consultative Organisation (IMCO))
   - 3.2 International Association of Classification Societies (IACS)
4. POST 1948
   - 4.1 Load Line Convention 1966
   - 4.2 Safety of Life at Sea Conventions
   - 4.3 International Convention for the Prevention of Pollution from Ships 1973 and its associated Protocol of 1978
   - 4.4 Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk
   - 4.5 International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk
   - 4.6 Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
   - 4.7 Code for Existing Ships Carrying Liquefied Gases in Bulk
   - 4.8 International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
   - 4.9 Tonnage Measurement
   - 4.10 Crew Accommodation
   - 4.11 Torremolinos International Convention for the Safety of Fishing Vessels 1977
   - 4.12 Code of Safe Practice for Solid Bulk Cargoes
   - 4.13 Other Notable IMO Codes
5. IMPLEMENTION OF CONVENTIONS
6. PORT STATE CONTROL
7. THE PRESENT SITUATION
8. THE FUTURE
9. CONCLUSION
10. REFERENCES

1. INTRODUCTION

It is perhaps appropriate to summarise in this paper the development of International Conventions since 1948, a year which witnessed the birth of two Conventions both of which have had a profound effect on the overall operations of Lloyd's Register. The 1948 Safety of Life at Sea Convention and the Convention which established the International Maritime Organisation (IMO) previously known as IMCO.

2. PRE-1948

Lloyd's Register may be said to have entered into the field of Statutory Survey work in 1835 when the Committee proposed a freeboard of three inches per foot of depth of hold. This became known as Lloyd's Rule and was used extensively until 1880. Until this rule was developed and following the constitution of the Society in 1764, it had been the practice to record the load draught of each ship in the Lloyd's Register Book, the figure apparently having been decided by the Owner as being suitable for the ship and its trade.

Following pressure from Samuel Plimsoll, the United Kingdom parliament passed the Merchant Shipping Act of 1876, which required that all British and foreign ships leaving British

ports be marked with what we now know as a Load Line Mark, indicating the draught to which an Owner intended to load his ship on the next voyage.

In 1884, Mr. Benjamin Martell, then Chief Ship Surveyor to Lloyd's Register, presented a report to the Society's Committee which proposed that freeboard should be a condition of class. Freeboard tables were prepared and in 1886 these were adopted by the United Kingdom Board of Trade as requirements for British flag ships in excess of 80 registered tons.

Other maritime nations followed suit with different variations on the Lloyd's Register system, as adopted by the U.K., until 1932 when the 1930 Convention on Load Lines came into force. For the first time there was international agreement between maritime nations on the principles and methods to be used in calculating the freeboard of merchant ships, and on the conditions of assignment of these freeboards. Lloyd's Register was delegated authority to act on behalf of many Administrations, and its involvement in the field of Statutory Survey work thus became international.

The history of British Freeboard regulations was covered in two L.R.T.A. papers by W. Watt (Refs 1 and 2).

The safety of ships is dependent not only on the adequacy of structure, main and auxiliary machinery, as ensured by Classification and on weathertight integrity, as provided by the Load Line Convention, but also on the capability to survive flooding. The means for preventing a fire or to detect and fight it, the availability of lifesaving appliances and the provision of adequate stability are other basic physical elements of safety.

Although early safety regulations, other than Load Line rules, had been formulated by some countries, they were mainly concerned with passenger ships and administered solely by Government departments.

Safety Conferences held in 1889 and 1913 were inconclusive, the first because the time was not ripe, the second because of the First World War. It was not until 1929 that a Safety Convention was agreed upon which came into force also in 1932. It incorporated the basic principles of subdivision, formulated in 1913, following the TITANIC disaster, which were elaborated to take account of the experience gained in the intervening period.

This Convention dealt with stability, subdivision and lifesaving appliances for passenger ships but did not include requirements for fire detection or extinction, except in relation to the carriage of dangerous goods. No safety regulations were drawn up for cargo ships apart from those concerning radio installations and the carriage of dangerous goods.

3. 1948 SOLAS

In the periods before and after the second world war there was a rapid growth in the transport of oil in bulk. The general use of oil fuel and the increase in the size and speed of ships introduced new hazards, resulting in a considerable increase in the number of serious fires, explosions and loss of life at sea.

The International Conference on Safety of Life at Sea which was convened in 1948 addressed these problems and the resulting convention, which came into force in November 1952, introduced new requirements for fire protection in passenger ships, including three basic methods of structural fire protection, and safety equipment for cargo ships.

All cargo ships registered in contracting countries were for the first time required to be provided with a Safety Equipment Certificate and a Safety Radiotelegraphy or Radiotelephony Certificate.

An L.R.T.A. paper about the 1948 Convention was written by S.T. Bryden, J.R. Beveridge and G.O. Watson (Ref 3).

For maritime countries with experienced Administrations and well established industries, the survey of ships and issue of the required documents was a relatively simple matter. The continued growth, however, of other established National Merchant Fleets, the birth of new independent states who had developed their own fleets, coupled with the revision of existing International Conventions or the appearance of new ones, caused a demand on technical skills which most governments found, and still find, difficult to meet. As a result, a great number of National Administrations turned to the Classification Societies, such as Lloyd's Register, to act on their behalf, especially as they realised that in general the Societies were able to offer a worldwide service which would ensure continuous control of ships of their flag wherever they may happen to be.

The coming into force of the 1948 SOLAS Conventions was therefore, as previously mentioned, a significant point in the development of Lloyd's Register activities in the field of Statutory work.

Having been previously involved only with classification work and the closely associated Load Line rules, the field Surveyors at that time, not surprisingly, found difficulty in dealing with the new legislation and its interpretation, W. Macmillan presented a paper to the L.R.T.A. on the 'Survey of Safety Equipment' (Ref 4) which must have been of considerable assistance.

3.1 International Maritime Organisation (IMO) (formerly Inter-governmental Maritime Consultative Organisation (IMCO)).

Prior to 1948, International Conferences on Safety at Sea had been convened at the invitation of the Government of the United Kingdom. In 1948 however, IMCO was established at a Conference promoted by the United Nations at Geneva. The Convention produced by the Conference entered into force in 1958. The idea, first expressed at Washington in 1889, had thus become a reality and for the first time there existed an international organisation which could keep safety requirements under continuous review and address new problems as they occurred. IMCO changed its name to IMO in 1982.

IMO is one of the specialist agencies operating within the framework of the United Nations. It has its headquarters in London and the principal organs within the structure of the Organisation are the Assembly, the Council, the Maritime Safety Committee (MSC) (which monitors and controls the work of various Sub-Committees) and the Maritime Environment Protection Committee (MEPC). There are other divisions such as Legal, Administration, Technical Co-operation, etc. which are normally outside the technical interest.

The MSC deals with technical subjects relating to safety and, acting through the Council, is required to submit to the Assembly proposals made by Members for safety regulations, or for amendments to existing safety regulations, together with relevant comments and recommendations.

The MEPC deals with subjects relevant to the protection of the marine environment and conforms with the procedures expected from the MSC. These two Committees have equal status in the Organisation.

The Assembly, at which all Member States are represented, holds its regular session once every two years, whereas, the Council (which is elected by the Assembly), MSC and MEPC meet approximately three times every two years.

In addition to the matters dealt with by the MSC and MEPC, and those subjects considered by the Legal Committee for presentation to the Assembly, IMO acts as depository for a series of international agreements in the field of maritime traffic and maritime law.

Membership of IMO is open to any member state of the United Nations and also to other states under prescribed circumstances. The Organisation now has a total membership of 131 countries. All of these countries have the same voting power, the size of the merchant fleet of any particular country having no influence on the value of its vote.

The technical effort made by IMO in its relatively short life has been formidable. It is now responsible for 21 international conventions and agreements and has adopted no fewer than 32 different protocols or amendments. Additionally well over 600 Resolutions have been approved by the Assembly.

Resolutions of a technical character fall into four main groups; amendments or additions to existing Conventions; codes of practice aimed at special types of ships; performance standards for systems and equipment; other recommendations which do not fall into any of the other categories.

The acceptance of amendments to Conventions is subject to ratification in accordance with the procedures laid down in the parent Convention. The implementation of Codes and other Resolutions is entirely at the discretion of national administrations.

There have been three distinct phases in the development of IMO; from 1958 to 1970 when the organisation firmly established itself and promoted three major conferences; the period from 1970 to 1980 which saw an accelerated rate of production of Conventions; and from 1980 onwards which is intended to be a period of fulfilment and consolidation.

3.2 International Association of Classification Societies (IACS)

In the years following the ratification of the IMO Convention there was very little effort made to institute close relations between this new UN agency and the Classification Societies. It was not in fact until the late sixties when a change in attitude took place, which was probably brought about by the way in which IMO activities were beginning to encroach on matters which hitherto had been almost exclusively the concern of Classification Societies, and to a change in the rules of membership of IMO. The need for wider consultation brought about these changes which allowed the Assembly to grant consultative status to any non-governmental organisation able to make a substantial contribution to the work of the organisation.

The major Classification Societies had been meeting informally over some 35 years but the formation of a Load Line Working Party in 1966, initially to deal with a problem of interpretation very soon after the 1966 Load Line Conference had ended, led to the formation of other working parties and resulted in the founding of IACS in 1968.

In addition to Lloyd's Register, membership includes:–

American Bureau of Shipping
Bureau Veritas
Germanischer Lloyd
Nippon Kaiji Kyokai
Det norske Veritas
Polish Register of Shipping
Registro Italiano Navale
Register of Shipping of U.S.S.R.

Associate members include:–

Jugoslav Register of Shipping
Korean Register of Shipping
DDR-Schiffs-Revision and Klassifikation

IACS was granted consultative status at IMO in 1969. Membership of IACS enables the Classification Societies to make active contributions to current thinking through IMO and keeps them fully up to date over the whole field of maritime safety. They are thus in a position to ensure compliance with the requirements of the various IMO Conventions and also to understand the different interpretations put upon the regulations by Governments throughout the world.

In common with other Classification Societies, Lloyd's Register has no access to IMO in its own right. It is, however, represented:

(a) Through its membership of IACS, at all meetings of the Maritime Safety Committee, Marine Environment Protection Committee, and technical sub-committees of IMO.

(b) On the United Kingdom delegations to many of the IMO sub-committees. It also collaborates with the Department of Transport and General Council of British Shipping in the deliberations of various working parties.

(c) As a delegate for Liberia on the IMO Maritime Safety and Marine Environment Protection Committees and the sub-committees on Subdivision and Stability, Ship Design and Equipment, Carriage of Dangerous Goods, Containers and Cargoes, Lifesaving Appliances, Fire Protection, Safety of Navigation, Radio Communications and Bulk Chemicals. Lloyd's Register is, by this involvement, represented on specialist ad hoc groups within the various sub-committees where its expertise can be utilised to the full.

A more detailed account of Lloyd's Register's relations with IMO and IACS was given by R.P. Harrison (Ref 5).

4. POST 1948

Since the coming into force of SOLAS 1948 in 1952, Lloyd's Register has become increasingly involved in statutory work and now applies a large number of Conventions and Codes on behalf of Governments with varying degrees of authorisation. It is not the intention to cover the details of all the regulations being dealt with; apart from being impracticable in a paper of this type they have to a greater or lesser extent been dealt with in other publications.

The following notes under various headings therefore give a brief indication of developments which have taken place during the period under review.

4.1 Load Line Convention 1966

This Convention which came into force on 21st July 1968 was dealt with in detail by T.A. Simpson, J.M. Bates and L. Beckwith (Ref 6). It is therefore sufficient to mention that compared with the requirements of the 1930 convention many existing ships were allowed to load to a deeper draught provided that their scantlings were suitable and that they complied with the more stringent conditions of assignment laid down.

Two particular features which were introduced for the first time into a Load Line Convention were the survivability concept for type 'A' and type 'B' ships with reduced freeboards, and the requirement that the master be provided with loading and stability information in an approved form.

The majority of administrations which authorise Lloyd's Register to assign Load Lines also delegated the work of ensuring compliance with the survivability requirement. This involved the setting up of a small headquarters group to deal with the matter and the purchase of suitable computer software. This group now also deals with survivability criteria which were later introduced into other Conventions and Codes.

Prior to the advent of the 1966 Load Line Convention, matters of stability were dealt with primarily by the major Maritime Administrations. The SOLAS Convention contained requirements for the provision of stability information to cargo ships without specifically stating that it should be approved, with the consequence that practices varied from one administration to another.

The introduction of the requirement for stability information mentioned above brought about a more positive attitude by Administrations and many of them interpret the statement 'in an approved form' to mean that the data should be fully examined and approved.

Whilst many of the major administrations continue to perform this function, others for various reasons delegate it to Lloyd's Register for ships classed with the Society. This involves the verification of basic stability data, witnessing and approval of inclining tests as well as the examination and approval of the final Trim and Stability Manual.

Whilst guidance regarding stability criteria to be applied can be obtained from IMO or the national administration, new types of ship are constantly being developed, consequently it is necessary to keep abreast of developments and consider special stability problems as they arise.

As with the survivability requirements it was necessary to set up a small group to deal with intact stability matters. This group also deals with the closely related grain stability requirements of the latest SOLAS Conventions.

4.2 Safety of Life at Sea Conventions

In the twelve years following the development of the 1948 Convention further developments had taken place which necessitated another conference in 1960. The resulting 1960 SOLAS Convention came into force on 26th May 1965 completely replacing SOLAS 1948. It applied to all cargo ships of more than 500 tons gross and all passenger ships engaged on international voyages. It is in fact still in force for those countries which have not yet ratified SOLAS 1974.

All ships were required to comply with regulations concerning structural fire protection, fire detection and extinction, lifesaving appliances, radio communications, and also with the current collision regulations. In addition passenger ships were required to comply with regulations concerning subdivision and damage stability. Whereas previous Conventions had included requirements for the hull and machinery of passenger ships, measures were introduced into the 1960 Convention which required for the first time the survey of the hull, machinery and equipment (including emergency sources of electrical power), steering gear and structural fire protection arrangements.

This latter requirement was another milestone in the development of statutory work within Lloyd's Register as, although it may not have been recognised at the time, it drew Classification closer to international requirements.

As all the items listed for the issue of a SAFCON Certificate were familiar to the Classification Societies, it is not surprising that a large number of the Administrations delegated the work to them and of these a majority also delegated the issue of the certificate.

At this point mention should be made of important associated regulations referred to in SOLAS Conventions, the International Regulations for Preventing Collisions at Sea 1972. The previous regulations (Annex B of SOLAS 1960) were extensively re-written and extended in scope, particularly in respect of range, position and colour specification of navigation lights.

The new regulations have been applicable to new ships since July 1977. Certain exemptions were allowed for existing ships but ships constructed before 15th July 1977 were required, by 15th July 1981, to be fitted with approved navigation lights complying with the ranges prescribed in Rule 22 and with the colour specifications listed in Section 7 of Annex I of the Regulations.

The repositioning of masthead and sidelights and compliance with the requirements of sound signal appliances for all ships should have been dealt with by 15th July 1986.

The 1974 SOLAS Convention, in force since 26th May 1980, has now been ratified by most of the major maritime nations. It is essentially an update of the 1960 SOLAS Convention and includes all the amendments adopted by IMO since the implementation of that Convention.

The principal differences between SOLAS 1960 and SOLAS 1974 are:–

(i) The requirements for fixed gas fire-extinguishing systems in machinery spaces were revised.

(ii) The requirements for fixed foam fire-extinguishing systems in machinery spaces were amplified. New requirements for high-expansion foam fire-extinguishing systems were given (low-expansion foam systems as the only fixed system, other than the fire main, are not permitted).

(iii) The requirements for pressure water-spraying fire-extinguishing systems in machinery and other spaces were made more explicit.

(iv) New fire safety measures were introduced for tankers i.e. inert gas systems and fixed deck foam systems for tankers of 100,000 DWT and over and combination carriers of 50,000 DWT and over.

(v) The lifesaving requirements were revised and requirements for additional navigational aids introduced.

(vi) The IMO equivalent grain regulations (Resolution A264 (VIII)) were incorporated into the Convention.

(vii) New tacit amendment procedures were introduced.

The latter point is important and fundamental to the early introduction of further legislation on safety, it being remembered that the 1948 SOLAS Convention took four years to enter into force, the 1960 Convention five years and the 1974 Convention six years! New procedures for amendment of the SOLAS Convention were agreed in 1974 in order to accelerate their implementation. Agreed Amendments to the 1974 SOLAS Convention will enter into force automatically after two years, or a shorter period of not less than one year, unless more than one third of the Contracting Governments or Contracting Governments whose combined fleets constitute not less than 50% of the world's merchant fleet, register an objection.

As a consequence of the new amendment procedure two sets of amendments were adopted by IMO in 1981 and 1983.

The 1981 Amendments, in force since 1st September 1984, made the following changes to the 1974 Convention:–

(i) Chapter II-1 for Subdivision and Stability, Machinery and Electrical Installations was completely re-written but the substance remains the same with the exception of modifications to the requirements for steering gears, electrical installations and periodically unattended machinery spaces.

(ii) Chapter II-2 for Fire Protection, Detection and Extinction was completely revised introducing enhanced structural fire protection for cargo ships. New fire extinguishing media were taken into account, the requirements for inert gas systems enhanced, more stringent requirements for cargo ship emergency fire pumps introduced and the requirements for cargo tank venting in tankers increased.

(iii) There were new requirements for Ro/Ro cargo ships and special requirements for ships carrying dangerous goods.

(iv) Revised requirements for shipborne navigational equipment were introduced into Chapter V (Safety of Navigation) and are to be implemented on a phased basis.

The 1983 Amendments, in force since 1st July 1986, made the following changes to the 1974 Convention:–

(i) Minor changes to Chapter II-1 and further changes to Chapter II-2, which include improvements to the 1981 Amendments, designed particularly to increase the safety of bulk carriers and passenger ships.

(ii) Chapter III (Life Saving Appliances) was completely re-written. All new cargo ships are to have totally enclosed lifeboats for 100% of the crew on each side and liferafts capable of being launched on either side for 100% of the crew or for 100% each side of the ship if they cannot be easily transported from one side to the other. All lifeboats and rescue boats are to be 6 knot motor-propelled and there are changes to davit capabilities. An option to allow the use of free-fall lifeboats has been included.

(iii) Chapter VII which previously dealt only with dangerous goods in packages was extended to include the carriage of liquid chemicals and liquefied gases in bulk. The International Bulk Chemical Code and International Gas Carrier Code were incorporated into the Convention.

Further changes to the 1974 Convention were brought about by the 1978 Protocols to SOLAS 1974. As a result of a number of tanker accidents which took place around the coasts of the USA in 1977, IMO convened a diplomatic conference in London in February 1978, on Tanker Safety and Pollution Prevention – often now referred to as the TSPP Conference of 1978.

The objectives of the conference were to develop improved standards for the survey and certification of the construction

and equipment of oil tankers as well as increasing flag and port state control, the standards being related to oil tankers of 20,000 DWT and over.

The Conference considered two Conventions; SOLAS 74 and the Convention for the Prevention of Pollution in Ships 1973 which is dealt with later in this paper. It was recognised that any additions or modifications to Conventions not then in force would cause legal problems and accordingly it was decided that such additions and amendments as might be agreed should be considered as Protocols to the Conventions.

The TSPP Conference adopted two Protocols to form a package covering the requirements for surveys, inert gas systems, segregated ballast tanks, crude oil washing systems and steering gear, viz:–

(i) "Protocol of 1978 Relating to the International Convention for the Safety of Life at Sea 1974".

(ii) "Protocol of 1978 Relating to the International Convention for the Prevention of Pollution from Ships 1973".

The 1978 Protocol to SOLAS 1974 entered into force on 1st May 1981 and the principal requirements are:–

(i) Unscheduled Inspections for all cargo ships with an alternative of Mandatory Annual Surveys (so far no government has opted for Unscheduled Inspections).

(ii) Intermediate Surveys on tankers of 10 years of age and over.

(iii) Stricter Port State Control.

(iv) Size limitations, for tankers to be fitted with inert gas and fixed deck foam systems, reduced from 100,000 DWT to 20,000 DWT for new tankers. For existing tankers of 70,000 DWT and upwards an inert gas system to be fitted by 1st May 1983 and for tankers of 20,000 DWT and upwards but less than 70,000 DWT by 1st May 1985. Any tanker regardless of age operating with a Crude Oil Washing (COW) System to be fitted with an Inert Gas System.

(v) Additional steering gear requirements for new tankers of 10,000 tons gross and over and certain other less extensive modifications to be made to steering gears on existing tankers of 10,000 tons gross and upwards by 1st May 1983.

There are additional requirements for tankers concerning weather deck equipment, cargo pump room equipment and inert gas systems.

The requirement for substantial modifications to be made on existing tankers was a fundamental change from the tradition that, in the main, Conventions are not applied retrospectively.

Whilst the above survey requirements strictly apply only to ships flying the flag of contracting governments, Lloyd's Register decided to maintain uniform standards throughout the classed fleet. Where the periodic survey requirements referred to in the Protocol affected classification they were incorporated into the Rules for Surveys.

The scope of the various surveys required by the Protocol was not defined by the TSPP Conference. However, it did decide that 'Guidelines' should be prepared. These were issued as IMO Resolution A413(XI) – now amended by Resolution A465(XII) – and cover Mandatory Annual Surveys and Unscheduled Inspections of all cargo ships as well as Intermediate Surveys on tankers of ten years of age and over.

The guidelines are very comprehensive involving the examination of current certificates and records books, the survey of hull, machinery and equipment for cargo ships, the survey of life-saving appliances and other equipment (firefighting and navigation aids) of cargo ships.

The following notes apply to the application of various aspects of the SOLAS Convention by Lloyds Register.

4.2.1 Passenger Ships

These are required to be issued with a single Passenger Ship Safety Certificate, renewable annually. Apart from requirements which are fulfilled through classification, the Conventions include regulations concerning subdivision and damage stability, structural fire protection, fire detection and fire extinction, lifesaving appliances and radio communications. All Administrations accept classification of the hull and machinery with Lloyd's Register as a guarantee of compliance with the relevant items. Some Administrations deal with the other aspects but others rely on the Society to do the work for them.

The safety aspects of the issue of a Passenger Ship Safety Certificate are all dealt with by the International Conventions Department at Headquarters. All plans and calculations are dealt with and Surveyors from the department attend the shipyard to ensure compliance with convention requirements, the classification aspects being dealt with by the local Surveyors.

With the knowledge gained in recent years from dealing with large numbers of new ships and conversions it is doubtful whether any other organisation has more experience in the application of the latest requirements.

4.2.2 Cargo Ships

These are required to be issued with three distinct certificates:

(i) Cargo Ship Safety Construction Certificate.

(ii) Cargo Ship Safety Equipment Certificate (valid for up to two years).

(iii) Cargo Ship Safety Radiotelegraphy (or Telephony) Certificate (valid for up to one year).

4.2.3 Safety Construction

Mention has already been made of the requirements for the issue of a Safety Construction Certificate and its relationship with classification.

Prior to the 1978 Protocol related to the 1974 SOLAS Convention there was no specific limitation on the validity of the SAFCON Certificate although it was generally related to the validity of the Classification Certificate. The 1978 Protocol now limits it to five years and most Administrations require Mandatory Annual Surveys which are also dealt with by Lloyd's Register.

It is significant to mention that a number of Authorities who issue their own SAFCON Certificates have asked the Society to carry out Mandatory Annual Surveys on their behalf.

4.2.4 Safety Equipment, Radiotelegraphy and Radiotelephony

The SOLAS Conventions require that all cargo ships of 500 tons gross and over engaged in international voyages are to be provided with a Safety Equipment Certificate, covering lifesaving appliances, fire extinguishing arrangements and fire control plans. Ships of 300 tons and upwards but less than 1600 tons gross require a Radiotelephony Certificate, and those of 1600 tons gross and over require a Radiotelegraphy Certificate.

As with Mandatory Annual SAFCON Surveys a number of Administrations who issue their own Safety Equipment Certificates have asked the Society to undertake Mandatory Annual Safety Equipment Surveys on their behalf and to countersign the certificates.

The requirements for the issue of Safety Equipment and Radio Certificates have undergone a number of changes in subsequent conventions.

G. Smart dealt with the 1960 Convention (Ref. 7) whereas C.H.A. Marshall and J.V. Rugg have recently discussed the latest requirements (Ref. 8).

4.2.5 Fire Regulations

Arrangements and equipment for fire protection, detection and extinction on board ships are surveyed by Lloyd's Register when the responsibility for the issue of the various SOLAS Certificates is delegated to them by the flag state. Plans are submitted for approval in accordance with the regulations and surveys and check tests are carried out on board before any initial certificate is issued.

No separate certificate as such is issued for compliance with SOLAS fire regulations. It will be appreciated, however that, inter alia, the issue of a Passenger Ship Safety Certificate relates to fire protection, detection and extinction and general fire precautions, the Cargo Ship Safety Equipment Certificate to fire extinguishing appliances and fire control plans and the Cargo Ship Safety Construction Certificate to structural fire protection and general fire precautions.

Lloyd's Register has the opportunity to participate in the formulation of all new fire regulations instigated by IMO, being represented at all sub-committee meetings on fire protection by virtue of the IACS consultative status, and also by its association with certain national delegations. Fire regulations are continually under review, taking into account the development of new types of ship and the introducton of new fire resistant materials and fire fighting media. Lloyd's Register endeavours to keep in touch with all such developments through its contacts with industry, as well as through consultation within IACS and its knowledge of up-to-date thinking in IMO.

Where, in the interests of safety it is considered necessary, the Classification Rules are amended irrespective of whether international regulations have been promulgated.

Two papers have been presented to the LRTA on this subject by G. Coggon (Ref. 9) and D.J. Holland and C.M. Magill (Ref. 10).

4.2.6 Grain Loading

In the majority of cases where Lloyd's Register is authorised to approve intact stability data it is also authorised to approve Grain Loading information. Current approvals are carried out under the terms of Chapter VI of the 1974 SOLAS Convention, which incorporates the IMO Grain Regulations.

Whereas approvals under the Chapter VI of SOLAS 1960 involved the examination of plans of grain fittings as well as associated stability data, approvals under the latest regulations are in many cases limited to the vetting of the rather complicated grain heeling moment calculations which have to be carried out using the assumptions laid down in the regulations. Grain feeders are no longer needed and shifting boards are only required in certain compartments where it is necessary to reduce heeling moments in order to meet the stability criteria.

Computer programs have been developed which are used primarily to check submitted grain heeling moment calculations for both filled and partially filled compartments, and tables of allowable heeling moments which can be of assistance in meeting the stability criteria when loading grain cargoes of varying specific gravity.

With both intact and grain stability it is essential to keep abreast of the latest developments. This is done by having representation at the appropriate IMO Sub-Committee either through IACS or national delegations.

4.3 International Convention for the Prevention of Pollution from Ships 1973 and its associated Protocol of 1978

The concern expressed throughout the world about the effects of pollution on the marine environment resulted in a Convention aimed at the elimination of operational pollution at sea and a reduction in accidental pollution as a result of collision and grounding.

MARPOL 1973 consists of five Annexes; the first two, which were to be mandatory, covered respectively pollution by oil, and noxious substances in bulk, whilst the remaining three, which were to be optional, contained regulations for the prevention of pollution by harmful substances in packaged form, containers etc. sewage and garbage, in that order. The Convention as then written would have committed acceding Administrations to compliance with both Annexes I and II on entry into force but each signatory had the right to opt out of compliance with Annexes III, IV and V.

Due to certain difficulties, arising mainly from the requirements of Annex II, the necessary accessions were not forthcoming and it was not until the TSPP Conference adopted the Protocol to MARPOL 1973 that the problem was resolved. The Protocol, which legally separated Annexes I and II of MARPOL supplemented many of the Regulations contained in the original Annex I. In particular it extended it to existing tankers and introduced requirements concerning crude oil washing and protective location of segregated ballast together with the reinforcement of survey requirements. The result is a complex set of regulations which require reference both to Annex I of MARPOL 1973 and its associated 1978 Protocol. This problem was eased by the publication by IMO in 1978 of the booklet 'Regulations for the Prevention of Pollution by Oil' which combines the separate requirements.

MARPOL 1973/78 came into force on 2nd October 1983, but compliance with Annex I only was required on that date.

The main items introduced by the 1978 Protocol which are additional to the MARPOL 73 requirements are:-

(i) Unscheduled Inspections for all cargo ships with an alternative of Mandatory Annual Surveys – (so far no government has opted for Unscheduled Inspections).

(ii) Stricter Port State Control.

(iii) Segregated Ballast Tanks (SBT) plus Crude Oil Washing (COW) for new tankers of 20,000 DWT and over.

(iv) SBT or COW or the interim alternative of Dedicated Clean Ballast Tanks (CBT) for existing tankers of 40,000 DWT and over.

(v) Guidelines for Surveys under Annex I of MARPOL 73/78 have been issued by IMO as Resolution MEPC II(18). These guidelines are very comprehensive and cover Initial, Mandatory Annual, Intermediate and Periodical Surveys.

Because of the complexity of the regulations, which are dependent on type, size and age of ships, Lloyd's Register found it necessary to produce guidance tables summarising the construction and equipment requirements for each of the five categories of type and size and three categories of age. They also developed a procedure for Crude Oil Washing Installations and associated Inert Gas Systems. This information was incorporated into two documents (Ref 11) which was widely circulated throughout the shipping industries and (Ref 12) to all Surveyors. Some notes on the Regulations were also produced by J.R.G. Smith. (Ref 13).

In addition to the plan approval and surveys required for the installation of Crude Oil Washing piping and machines, also the associated Inert Gas System, a Cleanliness Survey and Oil on Top Survey is required. It was found necessary to train Surveyors specially for these surveys and a course was set up at the Society's Training Centre covering all aspects of the requirements.

MARPOL 73/78 – Annex II became effective on 6th April 1987 and is applicable to ships carrying any of the noxious liquid substances in bulk that are categorised and listed in the Annex. During the development of the Standards for Procedures and Arrangements required by the Annex, it became necessary to amend the original requirements of MARPOL 73 – Annex II. The amended regulations, which include requirements for chemical tankers to comply with the provisions of either the Bulk Chemical Code (BCH) or the International Bulk Chemical Code (IBC) as applicable, Standards for Procedures and Arrangements, and agreed interpretations of the provisions of Annex II, were published by IMO in July 1986 in a book titled "Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk".

As with Annex I this Annex contains many complex regulations and again it was necessary to produce guidance in the form of two booklets aimed particularly at operators, one for new and one for existing ships (Ref 14 and 15). C.M. Magill has also produced a paper on this subject (Ref 16).

There is little doubt that Annexes I and II of MARPOL 73/78

are the most complicated requirements yet to come out of IMO. They have caused problems for operators in implementation and to organisations issuing certificates of fitness in ensuring compliance.

The optional Annexes III, IV and V will enter into force twelve months after the date on which not less than 50% of the gross tonnage of the worlds merchant shipping have become parties to it.

4.4 Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (known as the Bulk Chemical Code, or BCH Code)

Until fairly recently, International Regulations had been concerned with the safety of ships, their crew, passengers and/or cargo. They are now becoming increasingly influenced by a new factor: the protection of the environment. The above Code was produced by IMO with both of these aspects in mind, taking into account the hazards of fire, health, water and air pollution and reactivity of the chemicals; the standards of safety expected being related to the degree of danger inherent in the cargo carried. Classification Societies, including Lloyd's Register, assisted in its formation. Adopted by IMO in 1971 the Code has since been amended eleven times.

Bearing in mind the probability of any damage to the hull, caused by collision or stranding, resulting in uncontrolled spillage of cargo into the sea which could have serious environmental effects in the case of some chemicals, the Code also includes requirements for the siting of cargo tanks and for floatability and damage stability.

Compliance with the Code has not until recently been mandatory but has been necessary for ships of all flags to enable them to trade in certain parts of the world. This has however, changed since, with the coming into force of MARPOL 73/78 —Annex II, compliance became mandatory for ships the keels of which were laid before 1st July 1986.

4.5 International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (known as the International Bulk Chemical Code, or IBC Code).

The requirements of this Code are, for practical purposes, the same as those of the BCH Code and the Amendments thereto. The IBC Code was incorporated into the 1983 Amendments to SOLAS 1974, thus compliance is mandatory for ships the keels of which were laid on or after 1st July 1986.

4.6 Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (known as the Gas Carrier Code, or GC Code).

The Classification Societies including Lloyd's Register have also taken a leading part, in the sub-committees of IMO, in the development of this Code. It seeks to cater for the hazards of flammability, toxicity, corrosivity and reactivity as well as the hazard which may arise due to the gases being transported under cryogenic or pressurised conditions. It prescribes design and constructional features and the equipment necessary to minimise the risk to the ship, its crew and to the environment having regard to the nature of the products involved.

This Code adopted by IMO in 1975 and amended four times since contains regulations similar to those to be found in the Chemical Tanker Code, but adapted to the hazards presented by different categories of gases and also to the constructional features of the type of ships to which it applies.

4.7 Code for Existing Ships Carrying Liquefied Gases in Bulk

The philosophy of this Code is similar to that of the Gas Carrier Code for new ships but the overall requirements are less onerous. The main differences are that there are no requirements for ship survival capability and cargo tank location in this code and, with regard to the electrical arrangements, the definitions of dangerous zones and dangerous spaces make the requirements less stringent.

Compliance with the GC Code or this Code is not mandatory but, like the BCH Code, has been necessary for ships of all flags to enable them to trade in certain parts of the world.

4.8 International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (known as the International Gas Carrier Code, or IGC Code)

The requirements of this Code are, for practical purposes, the same as those of the GC Code and Amendments thereto. The IGC Code was incorporated into the 1983 Amendments to SOLAS 1974, thus compliance is mandatory for ships the keels of which were laid on or after 1st July 1986.

4.9 Tonnage Measurement

At about the same time as the 1948 Convention came into force, Lloyd's Register was asked to undertake tonnage measurements on behalf of many of the same governments which asked it to issue safety equipment and radio certificates. There was at that time, and until just a few years ago, no truly international system of tonnage measurement and consequently measurements were carried out and tonnage certificates issued in accordance with national measurement rules.

The majority of Surveyors at that time had no experience whatsoever of tonnage measurement. Some were able to call on the Shipbuilder for assistance but many could not.

There was therefore a need for guidance, and this was provided by R. Gray and L. Beckwith (Ref 17).

All the existing systems of measurement started from the "Moorsom System" which was incorporated into the British Merchant Shipping Act of 1854. From time to time amendments were made to meet changed conditions and new types of ship, with the consequence that there were three main systems of measurement, viz: UK, USA and Oslo convention, in addition to Panama Canal and Suez Canal rules. There were also variants of all the main systems as adopted by various administrations with the result that Lloyd's Register was eventually applying seventeen different sets of regulations.

4.9.1 International Convention on Tonnage Measurements of Ships 1969

This Convention, which came into force on 18th July 1982, was intended to simplify tonnage measurement by the application of a universal system to replace the many national rules in operation which produce different tonnages depending on the country of registration, thus necessitating remeasurement on change of flag.

The new system perpetuates "gross" and "net" tonnage but is based on a volumetric measurement to moulded lines of the hull and enclosed spaces. It applies to all new ships and also to existing ships within twelve years of the Convention coming into force (by 19th July 1994).

Owners of existing ships may opt for remeasurement under the new rules at any time during this period. Complications have already arisen in that the tonnage of paragraph ships (i.e. ships of 499, 1599 tons gross etc.) will increase considerably. Thus many ships currently excepted could be brought within the scope of the SOLAS Conventions or more onerous existing requirements may become applicable.

To obviate this, an interim scheme for tonnage measurement of certain ships was agreed within IMO whereby, for SOLAS purposes, the owners of new ships could request that they also be measured under present national regulations until the end of 1984.

This interim scheme was later revised such that it does not apply to ships, the keels of which are laid after 31st December 1985, except:

(a) In respect of the requirements of Regulation 3 of Chapter IV of the 1974 SOLAS Convention for ships the keels of

which are laid before 18th July 1994, the Administration may continue to apply the interim scheme, and

(b) In respect of the regulations for cargo ships of less than 1,600 tons gross tonnage (as measured under national systems), the keels of which are laid after 31st December 1985, the Administration may continue to apply the interim scheme until 18th July 1994.

The scheme has now been further extended to also relate to the International Convention of Standards of Training and Watchkeeping for Seafareres, 1978, and MARPOL 73/78—Annex I, however the latter only applies to the regulations for ships of less than 400 tons gross as measured under previous national rules.

Computer programs have been developed to deal with the measurements for both new and existing ships (i.e. 1969 regulations and pre-1969 national regulations.)

Whilst it had been appreciated that there would be an increase in the volume of work in the period following the coming into force of the 1969 Convention it was hoped that eventually the new system would lead to a reduction of work, particularly in the case of ships changing flag. This is certainly not the case at present. The interim scheme mentioned above is one of the factors but an even bigger one is the attitude of the Canal Authorities. It had been hoped that they would eventually adopt the 1969 Convention and that ships would only need one tonnage certificate for all purposes. Unfortunately at the present time the Suez Canal Authorities have indicated their intention of retaining their present system of measurement and while the Panama Canal Company is studying the situation it will also be necessary to measure ships using their system. Consequently new ships being measured under the new Convention's simplified system must also be measured again under the complicated Canal measuring systems if they are to use the Canals.

4.10 Crew Accommodation

Due to the need to measure crew spaces for tonnage purposes, crew accommodation regulations have by tradition been associated with tonnage. Under the previous British Tonnage regulations master and crew spaces only qualified as deductible spaces if they were fitted in accordance with the accommodation regulations. Although the International Labour Organisation (ILO) has produced standards for crew accommodation (Conventions 92 and 133), the terms for ratification have not lent themselves to universal enforcement. Consequently there are no truly international regulations governing the survey and certification of Master and Crew Spaces. Many administrations apply the ILO standards but others have their own requirements.

Lloyd's Register does not generally become involved in surveys connected with accommodation when acting on behalf of Governments. It has however been given delegation to act in this connection on behalf of the administration on new ships flying the Greek flag in accordance with the national regulations. Liberia has adopted the ILO regulations for new ships and surveys may be carried out at the request of owners or builders. In recent months authorisation has been given to carry out crew accommodation surveys in accordance with ILO regulations on classed ships registered in the Norwegian International Ships Register (NIS).

Despite the fact that there are no mandatory international regulations owners have in recent years become aware of the importance of building to a recognised standard and it is not unusual for specifications to include the requirement that crew accommodation should comply sometimes with as many as three sets of national rules as well as with ILO. Compliance with these various rules can add to the resale value and assist when requiring certification on change of flag.

It is not the practice of Administrations, nor can they spare the expertise, to certify that a foreign flag ship complies with their own regulations. Builders have, therefore, turned to Lloyd's Register to examine plans and undertake surveys during the building stage for compliance with this or that set of regulations.

It is the practice of the Society to issue in such circumstances a statement on completion of the ship that, in its opinion the accommodation complies with the applicable published National Rules and Regulations or with the ILO Conventions. A rider is usually added, however, that this statement in no way implies that it would be acceptable to any particular Administration should the ship change its flag.

The procedures usually followed in such cases were described by J. W. Barron and J. R. G. Smith (Ref 18).

4.11 Torremolinos International Convention for the Safety of Fishing Vessels 1977

During the 1960's there was a series of serious accidents to fishing vessels in northern waters and it was well known that for many years the number of casualties in other parts of the world was high.

A conference was therefore called by IMO in Torremolinos in 1977 to address this problem.

The resulting Convention provides very detailed regulations which borrow much of their intent from the SOLAS 1974 and the 1966 Load Line Convention, with regard to weathertight integrity, bow height, fire protection, detection and extinction, lifesaving appliances etc. adapted to meet the particular needs of fishing vessels. Loading will be limited by consideration of stability and not by the assignment of Load Lines. Fishing vessels of length greater than 100 metres will be required to meet certain requirements for survival after flooding. There have so far been 15 ratifications of this Convention but these represent well below the 50% of the worlds gross tonnage required for it to come into force and it therefore looks as though it will be a very long time before it comes into force internationally although Administrations may incorporate its contents into national rules. There are however moves within IMO to make some amendments to the Convention which may make it more acceptable to some governments who have hitherto not been prepared to ratify it.

4.12 Code of Safe Practice for Solid Bulk Cargoes

In recent years there has been an increase in the variety of bulk cargoes carried by sea. Recognising the problems involved in the carriage of such cargoes IMO produced the Code as a recommended Guide to Administrations, Shipowners, Shippers and Masters on the standards to be applied in the safe stowage and shipment of solid bulk cargoes, excluding grain which is dealt with under SOLAS regulations. The Code includes advice on procedures to be followed, describes hazards associated with certain cargoes, gives lists of typical products currently being shipped and details of recommended test procedures to determine various characteristics of bulk cargo materials.

There is need to constantly update this Code and the IMO Sub-Committee concerned—Containers and Cargoes—has it permanently on its agenda. It will be appreciated that the carriage of many of these cargoes, if not carefully controlled, can bring about stability and in some cases structural problems. In the author's opinion these problems need careful attention in the near future.

At present the Code along with others of its type is not mandatory but recent incidents may soon bring about international requirements.

4.13 Other Notable IMO Codes

Code of Safety for Special Purpose Ships which was developed to provide an international standard of safety for such ships which by the nature of the work undertaken by them carry special personnel who are neither crew members nor passengers as defined by the SOLAS Conventions.

Code for the Construction and Equipment of Mobile Offshore Drilling Units which recognise that the design criteria for

such units are often quite different from conventional ships and that because of this International Conventions such as Safety of Life at Sea and Load Lines are inappropriate.

Because of the great fire risk involved in both mobile and fixed offshore installations it has been necessary to adapt both established marine practices and land based petro-chemical industry's requirements to meet the special circumstances involved. A paper on this subject was published by G. Coggon and C. M. Magill (Ref 19).

5. IMPLEMENTATION OF CONVENTIONS

Having reviewed the various conventions it is necessary to consider who is responsible for their implementation. This rests primarily with the Administrations of the contracting states but the Owners and masters of the ships also have a large part to play.

Each contracting state undertakes to establish national regulations based on the Conventions to which it is a party, and to provide survey and administrative services to control its own shipping, respond to requests made by other contracting states and to ensure that ships using its ports are properly certificated and maintained.

A contracting state is permitted by the various Conventions to delegate some of its powers to organisations such as classification societies, but in so doing it remains responsible for the effectiveness of surveys carried out on its behalf.

The master is duty bound to maintain his ship and its equipment in a satisfactory manner and to perform certain lifeboat and fire drills at regular intervals as prescribed in SOLAS 1974 and to record any defects found in the process. Under the terms of SOLAS 1974/78 the master is also duty bound to report any damage or defects on arrival at a port.

Finally it is the owner's responsibility to ensure that his ship is presented for survey or inspection at regular intervals as prescribed by the conventions. The fact that Lloyd's Register provides a reminder service by means of quarterly returns, which include the survey and certification status of a particular ship, does not relieve him of this responsibility.

6. PORT STATE CONTROL

The introduction of Port State Control has had a significant effect on the standards of maintenance of ships particularly in Europe and the United States. Procedures for the control of ships (Ref 20) were issued by IMO in 1982 and in the same year a memorandum of understanding on port state control was signed in Paris by 14 Maritime Authorities. The signatories agreed to inspect at least 25% of foreign flag ships visiting their ports in any one year and most of the signatories are now approaching this figure. There are still quite a number of governments who for various reasons have not ratified the Conventions and whose ships are sailing around with 'non convention' certificates. Although it must be said that many of the ships comply in all respects with the Conventions they nevertheless are subject to regular port state control inspection and sometimes delay in European and United States ports. By this means pressure is being put on the governments concerned to ratify at the earliest opportunity.

In other parts of the world, control may not at the moment be so strict, with the consequence that there are still "sub-standard" ships on the high seas. There is little doubt however that it will expand to other areas and that in the long term such ships will be virtually eradicated.

The classification societies have a big part to play in this in ensuring that surveys are carried out correctly and that at the time of survey the ship meets all requirements—classification and statutory.

7. THE PRESENT SITUATION

Lloyd's Register now acts on behalf of some 123 governments in a varying degree of delegation of surveying and certification in accordance with the Conventions and Codes previously mentioned.

In the early fifties the staff of the Freeboard Department consisted of 7 surveyors and 6 clerks, including 2 typists, dealing only with the assignment of freeboards and vetting of freeboard reports; acting on behalf of the major maritime nations of that time. The work of the department grew with the coming into force of the 1948 and 1960 SOLAS Conventions and in 1967 its name was changed to International Conventions to reflect the wider scope of the activities then being undertaken. Today there are about 70 technical staff in the various sections of the International Conventions Department with an administrations support staff of 50.

In the years since 1967 there has been a steady increase in the amount of statutory work undertaken both in headquarters and the field and the income from this work now represents about ten per cent of the worldwide income from all sources.

In the past seven years however, the pace of coming into force of legislation accelerated. Starting in 1980 with the coming into force of SOLAS 1974 continuing with the entry into force of the SOLAS 1974/78 Protocol in 1981, the 1969 Tonnage Convention in 1982, MARPOL 1973/78 Annex I in 1983, the 1981 amendments to SOLAS 1974 in 1984, the 1984 amendments to SOLAS 1974 in 1986, and MARPOL 1973/78 Annex II in 1987. In addition in 1986 and 1987 various aspects of the requirements became applicable to existing ships.

Apart from the extra work load which this legislation has placed on headquarters and field staff it has had a considerable effect on owners and ship operation. Not surprisingly owners have found difficulty in understanding some of the very complex regulations so that in addition to the publications previously mentioned (Refs 11, 14 and 15) a paper by J. R. G. Smith (Ref 21) and a booklet containing articles published in Lloyd's List (Ref 22) have been widely circulated.

The increase of the numbers of administrations delegating statutory surveys has to a large extent been due to the proliferation of developing nations becoming involved in maritime affairs and becoming members of IMO. Many of them have little or no maritime expertise and therefore look to the classification societies to act on their behalf.

Another interesting aspect however, has been the extension of delegation of statutory work traditionally done by many of the major maritime authorities. The demand on these authorities to carry out port state control duties, and produce legislation based on IMO documents, whilst at the same time being pressed by government to reduce staffing levels has in many cases compelled them to seek assistance, mainly from the major classification societies.

It must be emphasized that in giving such authorisation these authorities retain the ultimate responsibility and in consequence they have the right to monitor or in fact audit the activities of the certifying authorities if they so wish. Therefore in their role as agents to Governments, classification societies cannot act with complete independence, as they must respect any instructions which may be given by the respective administrations for the application of regulations which may be vague or ambiguous. In a Utopian world all such regulations would be interpreted in the same manner, but unfortunately, due to the large number of authorities concerned, this is extremely difficult to achieve. Those classification societies, such as Lloyd's Register which have the most mandates from Governments, are naturally more sensitive to the difficulties arising from different national interpretations and therefore make every effort to promote their unification. It is true, of course, that all Societies are interested in achieving such uniformity, but those which are of a more national character are not so vitally affected and are sometimes restricted in their outlook by their own Governments.

In this context it has been necessary to keep the surveying staff up-to-date with interpretations and new regulations by means of ICD/ICL letters which now number more than 200 and which hopefully are freely accessible in all ports.

8. THE FUTURE

It is almost certain that those involved in the work of the Freeboard Department in 1948 could not have envisaged the vast developments which have taken place since. It is equally certain that to attempt to forecast what will happen in the next forty years would be foolish.

What can be said is that the search will go on in the quest for improved safety at sea and that this will inevitably lead to stricter control. The classification societies including Lloyd's Register must be more and more involved in these processes.

When discussing IMO earlier in the paper it was mentioned that the period from 1980 was intended to be one of fulfilment and consolidation. A conference will be held in November 1988 to further this process. It will consider changes in the amendment procedures for both the 1966 Load Line and 1974 SOLAS Convention as well as amendments to Chapter I of SOLAS to allow for 5 year validity of cargo ship safety equipment and safety radio certificates and to look into the possibility of a 5 year certificate combining all the current SOLAS cargo ship certificates. This work will include the harmonization of the form of certificate, provisions for extending them, and the periodicity of surveys.

The IMO Sub-Committees will continue to monitor the conventions, one of the aims being to eventually produce an all embracing convention which will combine all the present conventions and codes. Items at present under active consideration are the intact stability of all ships and the sub-division of cargo ships. When the latter is resolved into a form of regulations the design of cargo ships will be considerably affected. A complete review of the Load Line Convention is also being considered.

Mention has already been made of further delegation of statutory work which has come about in recent years, it is anticipated that this will spread. Such delegation must inevitably mean working more closely with governments and being required to account for the work done on their behalf. While the liaison work will continue to be dealt with mainly through headquarters the responsibility of the field surveyor in carrying out the surveys cannot be ignored. It is essential that Lloyd's Register's high standards be seen to be maintained.

9. CONCLUSION

In the past forty years Lloyd's Register has become increasingly involved in the work of statutory surveys. This trend must inevitably continue and the Society must be closely involved with developments.

As Governments delegate more of this work to Classification Societies they will eventually lose expertise in particular subjects and this expertise will become the province of the societies. The societies will therefore exercise a greater influence on the development of ship safety. Consequently in view of the proliferation of minor societies in recent years it is essential that the major societies co-operate fully to ensure the effectiveness of such developments.

Finally it may be of interest to refer to a paper given by H. N. Pemberton (Ref 23), formerly Chief Engineer Surveyor to Lloyd's Register, in 1966. A number of the conclusions to this paper are in the authors opinion significant and some of them have to a large extent come to pass.

Quote:

Thus the overall picture of the future of classification may be summarised as follows:

(i) Under the SOLAS Convention most societies have become recognised by their own government, and in some cases by several governments, for the carrying out of surveys for SAFCON certificates.

(ii) The significance of a classification certificate is now overridden by that of the statutory certificate. The classification survey, however, will continue to offer an essential high quality technical service to owners.

(iii) The trend is towards uniformity of rule requirements which may lead to reciprocity between the various classification societies so that surveys and certificates of one will be accepted by the other. This will obviously lead to the surveying activities of societies being confined largely within their own national boundaries, with a consequent restriction in the breadth of experience available to each.

(iv) Classification societies are developing as survey authorities having responsibility to governments. If this continues voluntary submission by owners to a self-imposed discipline will in time disappear.

(v) Despite the above, the independent societies remaining, as they do, under the general direction of the shipowning and building industries, provide these industries with the means for influencing legislation by contributing a wide survey experience, specialist expertise, statistical analysis of service defects and the results of research.

(vi) The word "independent" applied to a classification society does not now mean independence of governments but independence in its total sphere of operations. Thus the society which can spread its technical people beyond the narrow limits of statutory survey duties and beyond the confines of its own national frontiers will acquire the greatest resources of knowledge and expertise of value not only to governments but essentially to the industries it exists to serve. This "independence" becomes of increasing importance in the years ahead when great technological advances involving fundamental changes in design and operating concepts are inevitable. The rational application of advances to ships to the economic benefit of shipowners is, in the authors view, a paramount responsibility of an independent society, and possibly the strongest incentive to shipowners to class with that society.

It is in this field that competition between societies can be healthy, and indeed, necessary. Without it societies must inevitably amalgamate into a world survey authority having predominantly statutory functions. This means technological stagnation.

Unquote.

These conclusions were reached more than 20 years ago!!

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